UNITED STATES DEPARTMENT OF AGRICULTURE

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Beef Cattle Breeding

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by

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U.S. Meat Animal Research Center

Animal Husbandry Research Division

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PREFACE

A systematic record-of-performance program is fundamental to genetic improvement in beef cattle. A clear understanding of genetic principles is essential for developing the most effective breeding practices using such records. This bulletin was prepared to acquaint beef cattle breeders and students of beef cattle breeding with the principles of genetic improvement and record of performance for traits that contribute to efficient production and desirability of product. This information will aid breeders in developing improved breeding practices that will increase the rate of genetic improvement in traits of economic value.

The principles of genetic improvement and record of performance discussed in this publication are based on results of research with beef cattle and other species. Much of the material that pertains specifically to beef cattle breeding has evolved from the three regional research projects on beef cattle breeding. These three regional research projects are cooperative between the State agricultural experiment stations and the Animal Husbandry Research Division, Agricultural Research Service, Department of Agriculture. The three regional projects are the North Central (NC–1), Western (W–1), and Southern (S–10).

The sections on "Use of Records," "Major Performance Traits of Beef Cattle," and "Central Testing Stations" have been written so that the reader can obtain some understanding of them with a minimum knowledge of the principles of genetic improvement. However, breeders interested in formulating the most effective breeding plans should also understand the genetic principles discussed in the other sections of this bulletin. Those desiring a more thorough treatment of genetic principles should refer to a textbook on the subject of animal breeding.

For further information and for details regarding specific programs, the reader should consult specialists in beef cattle breeding at his State land-grant college or university.

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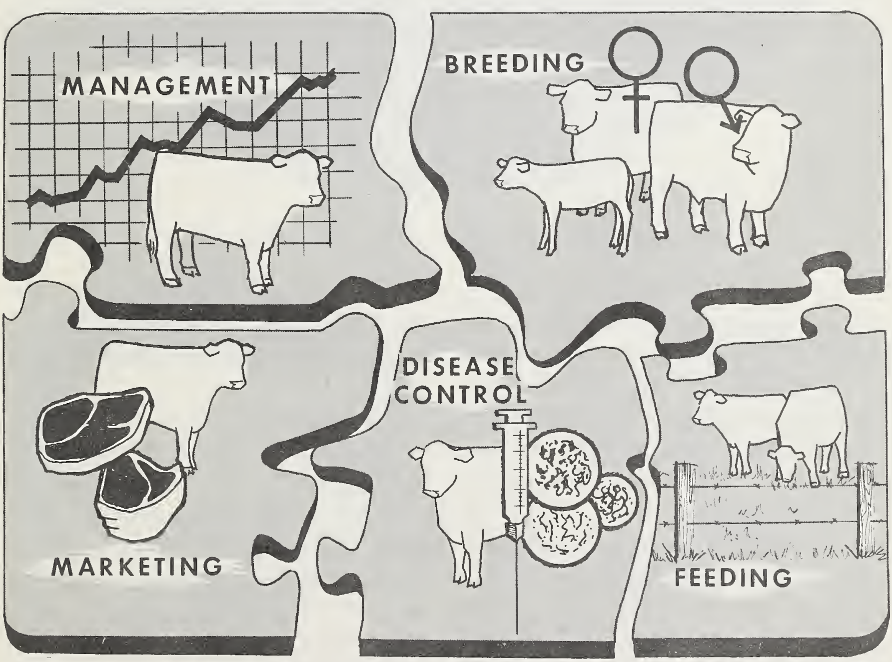
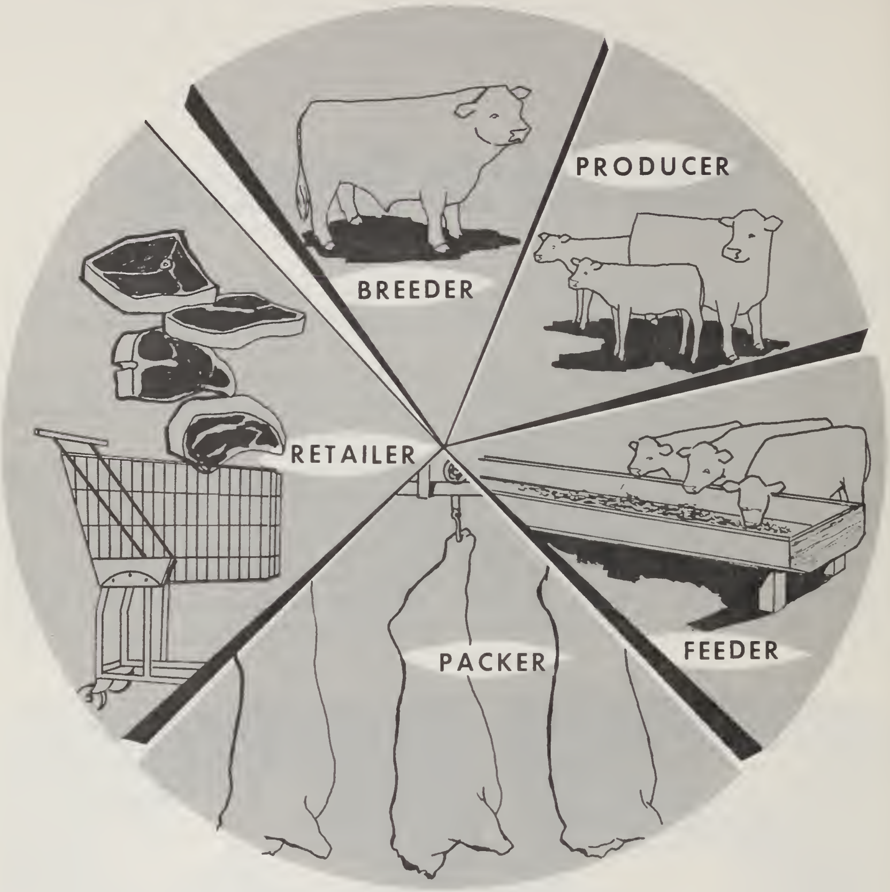
By Keith E. Gregory, *director, U.S. Meat Animal Research Center, Animal Husbandry Research Division, Agricultural Research Service*

The major objective of agriculture is the effective use of land. More than half of the land area in the United States is in grass. Beef cattle convert a large part of the production of this enormous land area into a highly palatable and nutritious product. More specifically, they convert the feeds produced on individual farms and ranches into a product in demand by consumers.

The major ways of improving productive efficiency and carcass desirability of beef cattle are through a knowledge of breeding, feeding, disease control, marketing, and management. This publication



Major factors that contribute to efficient production and carcass desirability in beef cattle.



All segments of the beef cattle industry are interdependent.

is concerned only with breeding, but a knowledge of all these areas is fundamental to the economical production of highly desirable beef. These areas may be viewed as a jigsaw puzzle, each of which contributes to completion of the picture of more efficient production of beef with greater consumer desirability.

The beef cattle industry in the United States is composed of several segments: (1) the purebred breeder or seedstock producer, (2) the commercial producer, (3) the feeder, (4) the packer, and (5) the retailer.

The purebred breeder of beef cattle maintains seedstock herds to provide bulls for the commercial producer. The commercial producer provides feeder stock to the feeder, who in turn provides the packer with finished beef cattle ready for slaughter. The packer slaughters the cattle and provides the retailer with either dressed car-

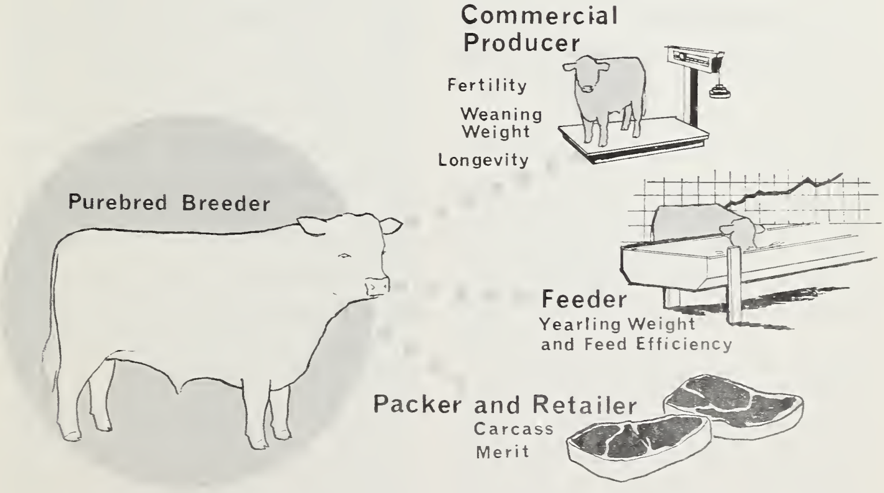
casses or wholesale cuts from these carcasses. The retailer breaks down the dressed carcasses or wholesale cuts into retail cuts, trimmed and packaged suitably for his customers, the consumers.

There is an interdependence among these segments because each affects cost of production or desirability of product, or both. Both desirability and price of product are reflected in changes in consumption. Level of consumption is important to all segments. Once a product is established, consumption depends primarily on its price and desirability. Consumption of beef depends primarily on how much it costs the consumers relative to other food items and how well they like it. The profits that accrue to all segments of the beef cattle industry depend on continued improvement in both productive efficiency and carcass desirability.

Only traits that contribute to productive efficiency and carcass desirability are of major economic importance to the beef cattle industry. These economically important traits, frequently referred to as performance traits, are (1) reproductive performance, or fertility, (2) mothering, or nursing, ability, (3) rate of gain, (4) efficiency of gain, (5) longevity, and (6) carcass merit.

THE RESPONSIBILITY OF THE PUREBRED BREEDER OR SEEDSTOCK PRODUCER

The opportunity for genetically improving traits of economic value rests primarily with the purebred breeder or in seedstock herds. Most



The purebred breeder is concerned with making genetic improvement in all traits of economic value in beef cattle.

of the opportunity for selection in beef cattle is among bulls. Level of performance in commercial beef cattle populations is determined primarily by the bulls available to commercial herds from the purebred segment of the industry. For the purebred breeder to discharge his responsibility to the other segments of the beef cattle industry with maximum effectiveness, an understanding of the functions of all segments is essential. The purebred breeder or seedstock producer should possess a working knowledge of genetics (the science of heredity) along with an appreciation of all traits of economic importance to the industry. In addition, he should understand the procedures for measuring or evaluating differences in these traits and be able to develop effective breeding practices for making genetic improvement in all traits that affect efficiency of production and desirability of product.

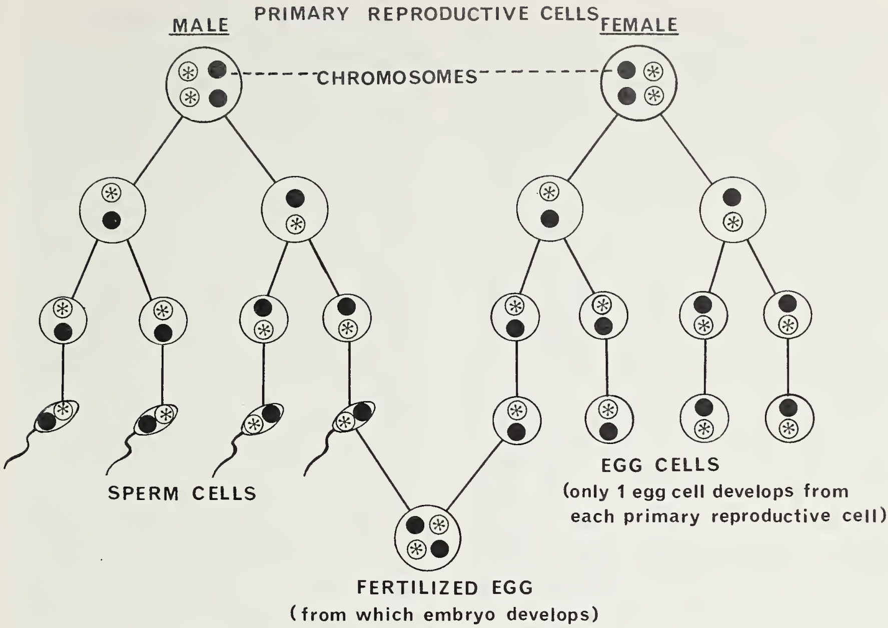
Expanding human populations will result in an increased demand for beef if present levels of consumption are maintained or expanded. The increase in population and the decreasing availability of land for beef production give impetus to increased productive efficiency. Further reductions in production costs relative to other foods are necessary if beef is to maintain and improve its position among other high-quality protein foods. Additional improvement in desirability of product will aid greatly in maintaining and improving the current acceptance of beef. Improved breeding practices based on systematic records of all traits of economic value should be a major factor in accomplishing these objectives.

THE BASIS FOR GENETIC IMPROVEMENT

An understanding of genetics is advantageous to anyone who wants to improve his livestock. This bulletin outlines some of the basic principles of genetics that provide a basis for genetic improvement in beef cattle.

Differences among animals result from the hereditary (genetic) differences transmitted by their parents and the environmental differences in which they are developed. With minor exceptions, each animal receives half its inheritance from its sire and half from its dam. The units of inheritance are known as genes and are carried on threadlike material, present in all cells of the body, called chromosomes. Cattle have 30 pairs of chromosomes. The chromosomes and genes are paired, each gene being at a particular place on a specific chromosome pair. There are thousands of pairs of genes in each animal and one member of each pair comes from each parent. All cells in an animal's body have essentially the same makeup of chromosomes and genes.

Special kinds of tissue in the ovaries of females and the testicles of males produce the reproductive cells. The reproductive cells contain only one member of each chromo-



Production of reproductive cells and fertilization (only two pairs of chromosomes are shown).

some pair, and it is purely a matter of chance which gene from each pair goes to each reproductive cell. In this halving process a sample half of each parent's inheritance goes to each reproductive cell. The genetic potentialities of an individual are determined at fertilization. The pairing of chromosomes restores the full complement when a reproductive cell from the male fertilizes a reproductive cell from the female. This restoration keeps the number of chromosomes constant over countless generations. Since the half of each of its parents' inheritance that each reproductive cell receives is strictly a matter of chance, some reproductive cells will contain more desirable genes for economically important traits than will others.

The union of reproductive cells that contain a high proportion of desirable genes for economically important traits results in a superior individual and offers the opportunity for selection. The chance segregation in the production of reproductive cells and recombination upon fertilization is the cause of genetic differences among offspring of the same parents.

The genetic merit of a large number of offspring will average that of their parents. However, some individuals will be genetically superior to the average of their parents and an approximately equal number will be inferior. Those that

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are superior provide the opportunity for selection and genetic improvement. The basis for genetic improvement is differential reproduction, which is accomplished by permitting some animals to leave a greater number of offspring than others or some to leave offspring while others do not. This is what happens when selection is practiced.

Genes vary greatly in their effects. Some traits are controlled primarily by a single pair of genes, whereas, other traits are affected by many genes. Examples of traits controlled primarily by a single pair of genes are dwarfism and color. Most of the economically important traits—carcass characteristics, growth rate, feed efficiency, and mothering ability—are affected by many genes. The thousands of genes present make countless combinations possible in any animal. Genes are too small to identify individually, and they manifest their presence by outward effects such as differences in growth rate, feed efficiency, and conformation.

In traits controlled by a single pair of genes, one member of the pair may be dominant. The dominant gene has the capacity for covering up, or masking, the effect of the other member of the pair. The gene masked is referred to as recessive. For example, the gene for polled masks the gene for horns when both are present. Polled is dominant and horned is recessive. Also, the gene for dwarfism is recessive to the gene for normal appearance. For example, if N represents the gene for normal appearance and n represents the gene for dwarfism, individuals with the "genetic makeup" of NN and Nn are normal in appearance, but Nn individuals carry the gene for dwarfism and transmit this gene to approximately half their offspring. Dwarfs (nn individuals) can result from mating normal-appearing parents if each carries the gene for dwarfism (Nn × Nn). Mating normal-appearing individuals that carry the dwarf gene (Nn × Nn) results in noncarriers (NN), carriers (Nn), and dwarfs (nn) in a 1 : 2 : 1 ratio.

Among animals, all differences that are not genetic are classified as environmental. Even though every attempt is made to provide a uniform environment, there are still random environmental differences among animals. For example, identical twins are exactly alike in their genetic makeup but differ in their performance because of random or chance environmental differences. All animals are not at exactly the same place at the same time, grazing the same area, and exposed to the same environmental elements. Some members of a group may contact infectious organisms while others do not. Another example might be injury to the udder of a cow, which would reduce her milk production and result in decreased weaning weight of her calf. There are many random environmental factors that may affect some members of a group and not others, and thus affect the expression of differences in economically important traits.

GENE FREQUENCY

The objective of selection for any performance trait is to increase in the population the number or frequency of desirable genes affecting that trait. This is accomplished by selecting animals that are above herd average in genetic merit.

Differential reproduction is the basis for change in gene frequency and genetic improvement. Culling animals that are poor in economically important traits reduces the frequency of undesirable genes in a herd if the culled animals are replaced by animals that are superior in those traits and thus have a higher percentage of desirable genes. Differential reproduction is the basis for continuous improvement in livestock. The increase of desirable genes in one generation is added to those of the previous generation. For this reason genetic improvement tends to be permanent.

Gene frequency refers to the percentage of the available locations that a particular gene occupies in a herd, or population. Since genes are paired in each animal, gene frequency includes both members of each pair and ranges from 0.00 to 1.00. For example, if a herd is free of dwarfism (NN), frequency of the dwarf gene in the herd is 0.00 and frequency of the gene for normal condition is 1.00; it occupies every potential location. Conversely, in a herd of dwarfs (nn), frequency of the dwarf gene is 1.00 and frequency of the gene for normal condition is 0.00. In a herd where all the animals are carriers of the dwarf gene (Nn), the frequency is 0.5 for both genes. Thus, the combined frequencies of both members of a gene pair is 1.00.

KINDS OF GENETIC VARIATION

Genetic variation is caused by either additive or nonadditive gene effects. Many genes are involved in the expression of each performance trait. When these genes produce their effects in a manner comparable to adding block upon block, as in construction of a building, their effects are referred to as additive. The result of selection is to increase the frequency of desirable genes that produce additive effects. The proportion of the total variation (genetic and environmental) due to additive gene effects is called heritability.

In the other basic type of genetic variation — nonadditive — specific combinations of genes produce special effects as a result of being present together. When specific combinations of genes produce a favorable effect, the genetic variation is referred to as hybrid vigor, or heterosis.

Traits vary in the degree to which they are controlled by these two kinds of genetic variation. For traits where most of the genetic variation is additive and it is large compared to the environmental variation, selection based on differences in individual performance will be effective. For traits where most of the genetic variation is nonadditive, selection based on differences in individual performance will be rela-

tively ineffective. For the latter type of trait, the breeding program must be designed to make use of specific crosses that produce favorable gene combinations. This involves crossing lines or breeds to obtain favorable combinations of genes for the expression of these traits.

A knowledge of the relative amounts of additive and nonadditive genetic variation that affect each economically important trait is fundamental to the development of an effective breeding program.

FACTORS AFFECTING RATE OF IMPROVEMENT FROM SELECTION

The factors affecting rate of improvement from selection are (1) heritability, (2) selection differential, (3) genetic association among the traits, and (4) generation interval.

Heritability

Heritability is the proportion of the differences between animals—measured or observed—that are transmitted to the offspring. Thus, it is the proportion of the total variation that is due to additive gene effects. The higher the heritability for any trait, the greater the rate of genetic improvement or the more effective selection will be for that trait. For traits of equal economic value, those with high heritability should receive more attention in selection than those with low heritability. Every attempt should be made to subject all animals from which selections are made to as nearly the same environment as possible. This practice will result in a larger proportion of the observed differences among individuals being genetic and will increase the effectiveness of selection. It is important to adjust for known environmental differences before making selections if the environmental factors can be evaluated. Adjustments can be made for differences in age, age of dam, and sex.

The average heritability estimates for some of the economically important traits of beef cattle are presented in table 1. Of the total difference between the selected individuals and the average of the population from which they were selected, the percentage indicated for each trait is actually transmitted to the offspring. For example, if the selected bulls and heifers were 30 pounds above herd average in weaning weight (selection differential), their progeny would be expected to average 9 pounds heavier than if no selection had been practiced for this trait ($30\% \times 30 = 9$).

These heritability estimates were obtained from a large number of research herds under carefully controlled environmental conditions and adjustments were made for known major environmental sources of variation. The heritability of any trait can be expected to vary slightly in different herds, depending on the genetic variability present and the uniformity of environment. However, estimates from different re-

Table 1.—*Heritability estimates of some economically important traits*

Trait	Heritability
	Percent
Calving interval (fertility)	10
Birth weight	40
Weaning weight	30
Cow maternal ability	40
Feedlot gain	45
Pasture gain	30
Efficiency of gain	40
Final feedlot weight	60
Conformation score:	
Weaning	25
Slaughter	40
Carcass traits:	
Carcass grade	40
Rib-eye area	70
Tenderness	60
Fat thickness	45
Retail product, percent	30
Retail product, pounds	65
Susceptibility to cancer eye	30

search herds have been reasonably consistent. The heritability estimates in table 1 probably represent average expectations for many herds, provided the general environment is similar for all cattle within the herd. These estimates indicate that selection should be reasonably effective for most performance traits. But since these traits vary both in heritability and economic importance, the rate of improvement in them and the emphasis that they should receive will also vary considerably.

Selection Differential

Selection differential is the difference between the selected individuals and the average of all animals from which they were selected. Selection differential is determined by the proportion of progeny needed for replacements, the number of traits considered in selection, and the differences that exist among the animals in a herd. If the average weaning weight of a herd is 450 pounds, and the individuals retained for breeding average 480 pounds, the selection differential is 30 pounds.

The relatively low reproductive rate of beef cattle usually necessitates keeping approximately 40 percent of the females for replacements if the herd is to be maintained and an even higher percentage if the herd is to be expanded. Most of the opportunity for selection is among the bulls, because a smaller percentage of the bulls must be saved for replacement. Increasing the number of traits selected for reduces the opportunity for selection for any one trait. Therefore, it is important to select only for traits of economic value that are heritable.

The low reproductive rate of beef cattle, which necessitates keeping a relatively high percentage (especially females) as replacements, and the large number of traits of economic importance that should be considered in selection place rather severe limitations on selection differentials possible for the various traits. Every effort should be made to get the maximum selection differentials possible for the traits of greatest economic importance and of highest heritability. Traits that have little or no bearing on either efficiency of production or desirability of product should be largely ignored.

Genetic Association Among Traits

A genetic correlation among traits is the result of genes favorable for the expression of one trait tending to be either favorable or unfavorable for the expression of another trait. Genetic correlations may be either positive or negative. If the association is favorable among traits on which selection is based, the rate of improvement in total merit is increased. Conversely, if a genetic antagonism exists among traits, the rate of improvement from selection is reduced.

Available information indicates a favorable association between rate and efficiency of gain and between growth rate in different periods. The only major unfavorable genetic association that has been reported among traits of economic value in beef cattle is a positive genetic correlation between outside fat thickness and marbling score.

Generation Interval

The fourth major factor that influences rate of improvement from selection is the generation interval, that is, the average age of all parents when their progeny are born. Generation interval averages approximately 4½ to 6 years in most beef cattle herds.

The progress made per generation in any trait is equal to the superiority of the selected individuals above the population average from which they came (selection differential), multiplied by the heritability of the trait. This can be put on a yearly basis by dividing by the average length of generation. For example,

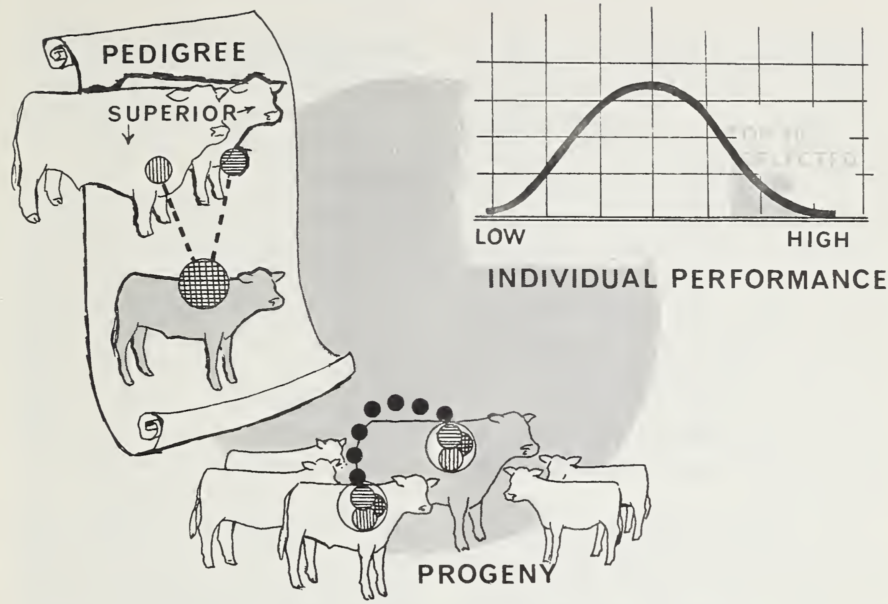
$$\text{Annual progress for a trait} = \frac{\text{Heritability} \times \text{Selection Differential}}{\text{Generation Interval}}$$

If heritability of yearling weight is 50 percent, the selected individuals (males and females) are 50 pounds heavier than the average of all animals, and the generation interval is 5 years. The rate of improvement per year in yearling weight would be $\frac{0.50 \times 50}{5}$ or 5 pounds. It is desirable to keep generation interval relatively short, consistent with obtaining near maximum selection differentials.

METHODS OF SELECTION

Selection may be based on (1) pedigree information, (2) individual performance information (mass selection), (3) progeny test or family performance information, or (4) a combination of all three.

Pedigree information is most useful in selecting among young animals before their own performance or their progeny's performance is known. Pedigree information may also be used in selecting for characters that are measured late in life, such as longevity and resistance to cancer eye, or when selecting for traits expressed only in one sex, such as mothering or nursing ability (selecting bulls that are progeny of cows that have produced calves with a high average weaning weight). Pedigree information should be given less attention after



Methods of selection: (1) On the basis of pedigree, or performance of ancestors; (2) on the basis of individual performance; and (3) on the basis of performance of progeny.

information on an individual's own performance or its progeny's performance is available.

Selection on an individual's own performance (mass selection) will result in most rapid improvement when heritabilities are high. An example of such a trait is growth rate. The advantage of selecting on individual performance is that it permits a rapid turnover of generations, or shortens the generation interval.

Use of progeny test information results in the most accurate selection if the progeny test is adequate. Progeny tests are most needed in selecting for carcass traits, if good indicators are not available in the live animal; for sex-limited traits, such as mothering ability (where individual performance information is not available on bulls); and for traits with low heritabilities. The advantage of using progeny test information over pedigree information and individual performance is accuracy, provided the progeny test is extensive. The disadvantages are the less intense culling possible because of the small proportion of animals that can be adequately progeny tested, the longer generation interval required to obtain progeny test information, and the decreased accuracy as compared with individual performance if not enough progeny are tested or if they are improperly evaluated.

All three types of information (pedigree, individual performance, and progeny test) should be used in

selecting beef cattle. When pedigree information is used, only the closest relatives should receive much consideration, since the more distant relatives can influence the heredity of the individual only through the close relatives (sire and dam). Information on the poor-performing ancestors should be considered along with the good-performing ones, because, on the average, the influence of all grandparents on the heredity of the indivdiual is the same. Also, both parents have an equal influence on the heredity of an individual.

In summary, pedigree information is useful if selections have to be made early in life before individual performance or progeny test information is available, in selecting for traits expressed late in life such as longevity and resistance to cancer eye, and in selecting for traits expressed only in one sex (mothering ability). Pedigree information is also useful in selecting against inherited defects such as dwarfism.

Individual performance information should be used for traits with high heritability that can be measured in the individual, such as growth rate.

After it becomes available, progeny test information should be used for all traits and is most needed for traits of low heritability, for certain carcass traits (that cannot be measured in the individual), and for sex-limited traits (traits expressed only in one sex).

A good policy is to make initial selections on the basis of pedigree and individual performance information and to determine the extent a bull is used in a herd in later years on the basis of progeny test information.

Research indicates that selection based on a combination of individual performance and progeny test information may result in the most rapid rate of genetic improvement for some traits (traits of low heritability or traits that cannot be accurately measured in the individual, such as carcass traits). However, for traits of high heritability that can be measured in the individual, selection on the basis of an individual's own performance is recommended. If progeny test information is used, it is essential that the test be designed so that the results can be properly evaluated. The purpose of a progeny test is to obtain the best estimate of the relative genetic merit of the bulls being tested. Therefore, it is necessary that the cows be assigned to the bulls at random. Selection of cows for a particular bull tends to "stack the cards" either for or against him. A convenient method is to classify the cows by age and line of breeding and to assign the cows to breeding groups at random within line of breeding and age of cow. The sires being progeny tested can then be assigned at random to the different breeding groups.

Table 2 provides information on the accuracy of selection on the basis of progeny test information with different numbers of progeny

TABLE 2.—*Accuracy of selection on the basis of progeny average (correlations between estimated and actual breeding value)*

Number of progeny	Heritability		
	0.10	0.30	0.50
1	0.16	0.27	0.35
2	.22	.37	.47
4	.30	.49	.60
6	.36	.57	.68
8	.41	.62	.73
10	.45	.67	.76
20	.58	.79	.86
50	.75	.89	.93
100	.85	.94	.97

per sire and at different levels of heritability. A correlation of 1.0 would reflect complete accuracy between estimated breeding value based on progeny test information and actual, or real, breeding value. It is obvious from table 2 that large numbers of progeny per sire are required in order to have a high accuracy in ranking sires on their breeding value.

TABLE 3.—*Comparative accuracy of selection based on progeny test information and selection based on individual performance information (progeny test/individual performance)*

Number of progeny	Heritability		
	0.10	0.30	0.50
1	0.50	0.50	0.50
2	.70	.68	.66
4	.96	.90	.85
6	1.15	1.04	.96
8	1.30	1.14	1.03
10	1.43	1.22	1.08
20	1.84	1.44	1.22
50	2.37	1.63	1.32
100	2.68	1.72	1.37

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Table 3 shows the comparative accuracy of selection on the basis of progeny test information relative to selection based on individual performance information with different numbers of progeny per sire and different levels of heritability. It is apparent from table 3 that about six progeny per sire are required to make progeny test selection approximately as accurate as individual performance selection at the three levels of heritability. For example, when heritabilities are 0.10, 0.30 and 0.50, progeny test selection with six progeny per sire have accuracies of 1.15, 1.04, and 0.96, respectively, as selection based on individual performance information. It is apparent that progeny test selection has greater relative value for traits with low heritability.

TYPES OF SELECTION

The three types of selection are (1) tandem selection, (2) selection based on independent culling levels, and (3) selection based on an index of net merit.

Tandem selection is selection for one trait at a time. When the desired level of performance is reached in this trait, a second trait is given primary emphasis, etc.

This is the least effective of the three types and is not recommended. Its major disadvantage is that, by selecting for only one trait at a time, some animals extremely poor in other traits will be retained as replacements.

Selection based on independent

culling levels requires that specific levels of performance be attained in each trait before an animal is kept for replacement. This is the second most effective type of selection. It has this disadvantage: In requiring specific levels of performance in all traits, it does not allow for slightly substandard performance in one trait to be offset by superior performance in another.

Selection based on an index of net merit gives weight to the various traits in proportion to their relative economic importance and their heritability and takes cognizance of the genetic association (if any) among the various traits. This is the most effective type of selection, because it allows slightly substandard performance in one trait to be offset by outstanding performance in another. Also, by giving additional weight to traits of higher heritability or greater economic importance, greater improvement in net merit can be attained.

The use of the index or some modification of it is the preferred type for most herds.

The larger the number of traits selected for, the slower the progress in any one of them; hence, the desirability of giving major consideration only to traits of economic value that have reasonably high heritabilities. The reason why differences in heritability of traits should be considered in selection is that the opportunity for selection should be used on traits that will respond. Obviously, if a trait has extremely low heritability, little genetic improvement in it can be expected. If such a trait is given attention, the emphasis that can be put on traits that give a greater response to selection (higher heritability) is reduced.

While traits of little or no economic importance or of low heritability should be given little or no attention in selection; all heritable traits of economic value should be considered concurrently, with the attention they receive being determined by their relative economic value and their heritability.

Although increasing the number of traits reduces the selection differential for any one trait, it results in more rapid improvement in total genetic merit, or net worth. Average reduction in progress in each trait as a result of considering several traits is approximately $1/\sqrt{n}$, where n is the number of traits selected for. For example, if four genetically independent traits are involved in selection, the selection differential for each of them will be approximately half what it would have been if only one trait was involved ($1/\sqrt{4}=\frac{1}{2}$). This is based on the assumption that there are no genetic associations (either favorable or unfavorable) among the four traits. It is obvious that considering all heritable, economically important traits simultaneously will result in more rapid improvement in genetic merit involving all traits.

It seems appropriate to consider (table 4) relative rates of improvement in some traits of economic

TABLE 4.—*Estimates of potential progress in 10 years when different intensities of mass selection are practiced for specific traits*[1]

Trait	Percentage of bulls saved: 1	10	20	50	70	Assumptions[2]
Weaning weight and						
No other traits ... pounds	41.6	30.6	26.4	19.2	15.6	50 percent of heifers saved; h^2, 0.3 in both sexes; S.D., 40 lb. in both sexes.
1 other trait ... do	29.4	21.6	18.7	13.6	11.0	
2 other traits ... do	24.0	17.7	15.2	11.1	9.0	
3 other traits ... do	20.8	15.3	13.2	9.6	7.8	
Postweaning daily gains and						
No other traits ... do	.44	.30	.25	.17	.12	50 percent of heifers saved; h^2, 0.5 in bulls, 0.3 in heifers; S.D., 0.29 lb. in bulls, 0.20 lb. in heifers.
1 other trait ... do	.31	.21	.18	.12	.08	
2 other traits ... do	.25	.17	.14	.10	.07	
3 other traits ... do	.22	.15	.12	.08	.06	
Yearling weight and						
No other traits ... do	147.4	103.2	86.4	57.6	43.2	50 percent of heifers saved; h^2, 0.6 in bulls, 0.4 in heifers; S.D., 80 lb. in bulls, 60 lb. in heifers.
1 other trait ... do	104.2	73.0	61.1	40.7	30.5	
2 other traits ... do	85.0	59.5	49.8	33.2	24.9	
3 other traits ... do	73.7	51.6	43.2	28.8	21.6	
Yearling conformation score and						
No other traits ... units	1.39	1.02	.88	.64	.52	50 percent of heifers saved; h^2, 0.4 in both sexes; S.D., 1 unit in both sexes.
1 other trait ... do	.98	.72	.62	.45	.37	
2 other traits ... do	.80	.59	.51	.37	.30	
3 other traits ... do	.70	.51	.44	.32	.26	

[1] Assumes that selection is only for the criteria indicated and when selection is for more than 1 trait, each trait is given equal emphasis and that the traits are inherited independently. Generation interval, 5 years.

[2] h^2, heritability; S.D., standard deviation—an estimate of variation.

value with different selection intensities or different percentages saved for breeding. These estimates are based on phenotypic evaluation for the traits indicated. Assumptions involved in these estimates are indicated in the table. The estimates presented are based on the assumption that the percentage saved and used produce progeny that have an opportunity to be selected for the next generation, i.e., the selected bulls from each generation are sired by bulls selected by the same criteria in the previous generation. The advantages of saving bulls from among the top and selecting only for traits that have real economic value are obvious from table 4.

MATING SYSTEMS

There are five fundamental types of mating systems: (1) random mating, (2) inbreeding, (3) outbreeding, (4) assortative mating, and (5) disassortative mating.

Random mating is the mating of individuals without regard to similarity of pedigree or similarity of performance (phenotype).

Inbreeding is the mating of individuals that are more closely related than the average of the breed or population. Linebreeding is a form of inbreeding.

Outbreeding is the mating of individuals that are less closely related than the average of the breed or population. Crossbreeding is a form of outbreeding.

Phenotypic assortative mating is the mating of individuals that are more alike in performance traits (phenotype) than the average of the herd or group.

Phenotypic disassortative mating is the mating of individuals that are less alike in performance traits (phenotype) than the average of the herd or group.

Inbreeding and outbreeding refer to similarity of pedigree or relationship, and phenotypic assortative and disassortative mating refer to phenotypic resemblance (likeness in performance traits). Phenotype refers to individual performance in all traits that can be measured in an individual.

Linebreeding is a special kind of inbreeding. Linebreeding is the mating of individuals so that the relationship to a particular individual is either maintained or increased. This method automatically results in some inbreeding, because related individuals must be mated to accomplish it.

Inbreeding normally has some adverse effects on most performance traits or results in some reduction in general vigor. However, herds of reasonable size, where several sires are used, can be maintained closed to outside breeding for relatively long periods without any appreciable increase in inbreeding or decline in performance associated with inbreeding.

Within a closed herd where the mating is random as far as relationship is concerned, the rate of increase in inbreeding per generation is $1/8m+1/8f$, where m is the total number of males used in each generation and f is the total number of

females in the herd in each generation. Thus, in a 100-cow herd where four sires are used per generation with 100 cows in the herd per generation, the increase in inbreeding per generation is $1/8(4) + 1/8(100) = 1/32 + 1/800 = 0.031 + 0.0012 = 0.0322$, or 3.22 percent per generation. If generation interval is 5 years, 15 years on such a program would result in a herd with average inbreeding of 9.66 percent. This is not a very rapid rate of inbreeding. For example, the mating of half brothers and sisters results in offspring that are 12.5-percent inbred. Offspring of sire-daughter, son-dam, and full brother and sister matings are 25-percent inbred. Sire numbers per generation are of paramount importance in affecting rate of inbreeding. The rate of inbreeding can be reduced by deliberately avoiding close matings such as sire-daughter and half brother and sister. Linebreeding will result in some loss of vigor, but if the animal to which a herd is being linebred is one of truly outstanding merit, the increase in performance as a result of intensifying the genes of an outstanding individual may more than offset any decline in performance due to inbreeding. Rigid selection accompanying linebreeding should be effective in reducing some of the undesirable effects of inbreeding. When inbred or linebred herds are outcrossed, the loss of vigor that accompanies inbreeding is restored.

Linebreeding and inbreeding make the individuals in a herd more alike genetically and thus more uniform in their transmitting ability. A major advantage of linebreeding and inbreeding is that a breeder knows his own herd better than he knows someone else's; thus, he is likely to do a more effective job of selecting from within his herd.

The effectiveness of linebreeding depends primarily on the genetic merit of the animal to which the linebreeding is directed.

Many breeders fear the consequences of inbreeding. Inbreeding intensifies what is already present in the herd, including poor traits as well as good. If an undesirable trait is present in the herd, inbreeding tends to bring it to "light." However, inbreeding is not the cause, as the genes responsible for the undesirable effect were already present. For example, if genes responsible for undesirable traits such as dwarfism are present in a population, inbreeding may increase the number of dwarf calves born, but it is not the cause of dwarfism.

Inbreeding may be used to evaluate the presence of undesirable genes in a herd. If accompanied by rigid selection, it may be effective in reducing the frequency of them.

The disadvantages of linebreeding and inbreeding are that the foundation animals may not be truly superior. A genetic defect in the foundation animals can by chance rise to a high frequency and greatly interfere with the breeding program and materially reduce the value of the herd regardless of its genetic merit for major perform-

ance traits. Because it reduces genetic variation, inbreeding results in decreased heritabilities and selection on individual performance is less effective. Since inbreeding makes individuals more alike in their genetic makeup, it increases the effectiveness of family selection.

In summary, linebreeding and inbreeding should be practiced only in herds of outstanding genetic merit. The herds should be large enough so that the rate of inbreeding will be slow enough to provide opportunity for selection before genetic variation is reduced to the point where selection is not effective. All commercial producers and purebred breeders with small herds or herds of only average genetic merit should avoid linebreeding and inbreeding.

Outbreeding is recommended for all commercial producers and for secondary seedstock herds. That is, close matings should be avoided. However, owners of secondary seedstock herds may profitably obtain bulls from linebred herds. If sources of linebred bulls are changed periodically for use in secondary herds, the system is still outbreeding. If it becomes necessary to outcross linebred herds to correct a deficiency, breeders may find it advantageous to outcross to other linebred herds that are particularly outstanding in the trait that needs improvement. After such an outcross it may be desirable to resume a program of linebreeding.

Many breeders practice both assortative and disassortative mating. Assortative mating is practiced by breeders to the extent that they mate their superior cows to their superior bulls. Likewise, they may mate the poorer cows to the unproved or less highly regarded sires. Disassortative mating is practiced when a breeder is attempting to make "corrective matings." That is, he may mate cows that are mediocre or poor in one trait to bulls he considers superior or outstanding in that trait. Assortative mating results in increased variation in a herd, while disassortative mating tends to reduce the genetic variation in a herd.

HETEROSIS IN COMMERCIAL PRODUCTION

Heterosis (hybrid vigor) is the result of nonadditive gene effects and is the difference in performance between crosses and the average of the parental breeds or groups used in the cross. Heterosis results from favorable combinations of genes or groups of genes brought about by specific crosses. Utilization of heterosis necessitates a form of outbreeding. Commercial utilization of heterosis depends on crossing breeds or groups that result in generally favorable genetic combinations.

The phenomenon of heterosis is used extensively in commercial swine and poultry production.

Evidence is accumulating that indicates that heterosis is of appreciable economic importance in beef cattle. Although the results vary some from different experiments and from crosses of different breeds, they

generally show a heterosis effect on early postnatal mortality, preweaning and postweaning growth rate, age at puberty, and in fertility and mothering ability of crossbred cows. The heterosis effects on feed efficiency have been small.

The results of heterosis effects on beef cattle traits confirm results with swine and poultry—that the level of heterosis is inversely proportional to heritability (additive genetic variation). Thus, in traits of highest heritability, such as postweaning growth rate and feed efficiency, the level of heterosis is relatively low; whereas, in traits with low heritability, such as liveability and fertility, the heterosis effects are relatively large.

On the basis of results from research many of the advantages to be gained from a systematic crossing program involve the use of crossbred cows. This is because of the relatively high levels of heterosis on fertility and mothering ability and the economic importance of these traits.

Preliminary results indicate that a systematic crossbreeding program may result in an increase of as much as 15 to 20 percent in pounds of calf weaned for cow bred over a program of straight breeding. This involves the cumulative heterosis effects on fertility, mothering ability, and preweaning growth rate.

The following is a summary of these results from an extensive crossbreeding experiment involving the Hereford, Angus, and Shorthorn breeds. These results are typical of what has been obtained from other experiments; they are given here because this represents the largest and most complete experiment of this kind that has been conducted.

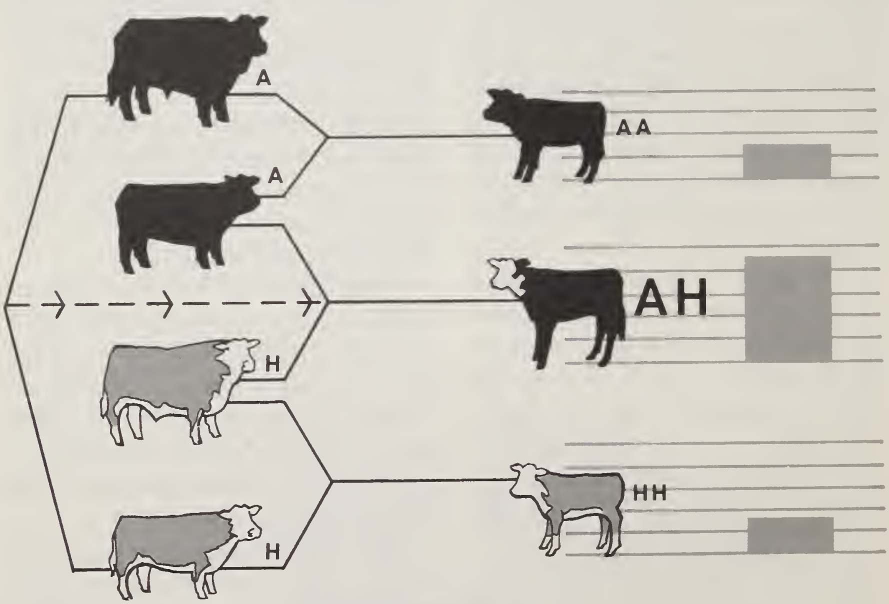
In the first phase of this experiment the three straightbreds and all reciprocal crosses among them were produced. Heterosis, or hybrid vigor, was evaluated by comparing the crossbreds with the average of the straightbreds. Crossbreds and straightbreds were sired by the same bulls and out of comparable cows. These studies involved an evaluation of the effects of hybrid vigor on embryo survival, postnatal mortality, birth weight, preweaning growth, weaning weight, weaning conformation score, postweaning growth rate, yearling weight, and age and weight at first heat of heifers developed under two management programs; postweaning growth rate, yearling weight, and postweaning feed efficiency of steers on a growing-fattening ration; and slaughter grade of steers.

Also detailed information was obtained on carcass characteristics of steers involving complete cutout data on one side of each carcass. These studies included a total of 751 calves from four calf crops sired by 16 Hereford, 17 Angus, and 16 Shorthorn bulls.

The effects of heterosis were significant for most of the economic traits evaluated. A 3 percent greater calf crop was weaned in the crossbred than in the straightbred calves, because of differences in early

postnatal mortality. The heterosis effect on 200-day weight was 24 pounds in heifers and 16 pounds in steers. The heterosis effect on post-weaning growth rate of heifers on a low level of feeding was greater than in steers on a growing-fattening ration. The magnitude of the heterosis effect on growth rate was related to level of feeding and age. That is, heterosis tended to decrease with increasing age after approximately 1 year, and heterosis was greatest on a restricted feed intake when comparing heifers with steers. The heterosis effect was 50 pounds on 550-day weight of heifers and 29 pounds on 452-day weight of steers. The heterosis effect on carcass weight at 452 days was 23 pounds for steers. Heterosis effects on age at first heat of heifers were 41 and 35 days for low and moderate levels of feeding, respectively. After adjusting age at puberty for the effects of average preweaning and post-weaning daily gains, approximately one-half to three-fourths of the heterosis effect on age at puberty (days) remained. Thus, the heterosis effect on age at puberty was independent of its effects through average daily gains.

The advantage of the crossbred steers in feed efficiency was small. The crossbred steers produced slightly fatter carcasses when killed at the same age. However, when adjustments were made for the effects of weight, there was no differ-



HETEROSIS

Effect of heterosis on some performance traits is important. The size of the bars at the right illustrate that, due to heterosis, productivity in some traits is greater in crossbred, or crossline, animals than in the average of the parental breeds or strains.

ence in carcass composition. Thus, if they had been slaughtered at the same weight, the composition of the carcasses would have been the same.

In net merit (value of the boneless, closely trimmed retail meat, adjusted for quality grade, minus feed costs from weaning to slaughter) the advantage of the crossbred steers over the straightbred steers was $8.81 (1965) per carcass. This net merit difference is among the steers that lived to slaughter. The 3 percent advantage for the crossbreds in calf crop weaned was not involved in computing this difference.

For growth, feed efficiency, and carcass traits the heterosis effect was greater in the Hereford-Angus and Hereford-Shorthorn combinations than for the Angus-Shorthorn combination; for age and weight at puberty the heterosis effect was greatest for the Hereford X Shorthorn and reciprocal cross. When all traits for the effects of heterosis are evaluated, it can be concluded that heterosis results in an increased rate of maturity.

The second phase of this experiment was started in 1963. This is to evaluate the effects of heterosis on fertility and mothering ability. That is, straightbred cows of the three breeds are being compared with their crossbred half sisters when both are bred to the same purebred bulls. For the 5 years 1963, 1964, 1965, 1966, and 1967, the advantage of the crossbred cows was 17, 6, 10, −3, and 11 percent, respectively, for calf crop weaned and 17, 31, 20, 22, and 27 pounds, respectively, in average weaning weight of calves at 200 days. These results of heterosis effects on cow performance traits (fertility and mothering ability) should be regarded as preliminary because data are still being collected from this phase of the experiment.

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Several questions have to be answered in regard to the most effective procedures for the utilization of heterosis in commercial beef production. Two major ones are what breeds to use and the number of breeds that may be used in a rotation of sires program for the maintenance of heterosis.

The effective utilization of heterosis in practice depends on using as breeding stock animals that are superior in their own performance in the traits that have high heritability (additive genetic variation). Not only is the use of superior purebred bulls essential but also additional attention is required to find specific strains or breeds that combine most favorably with the female herd.

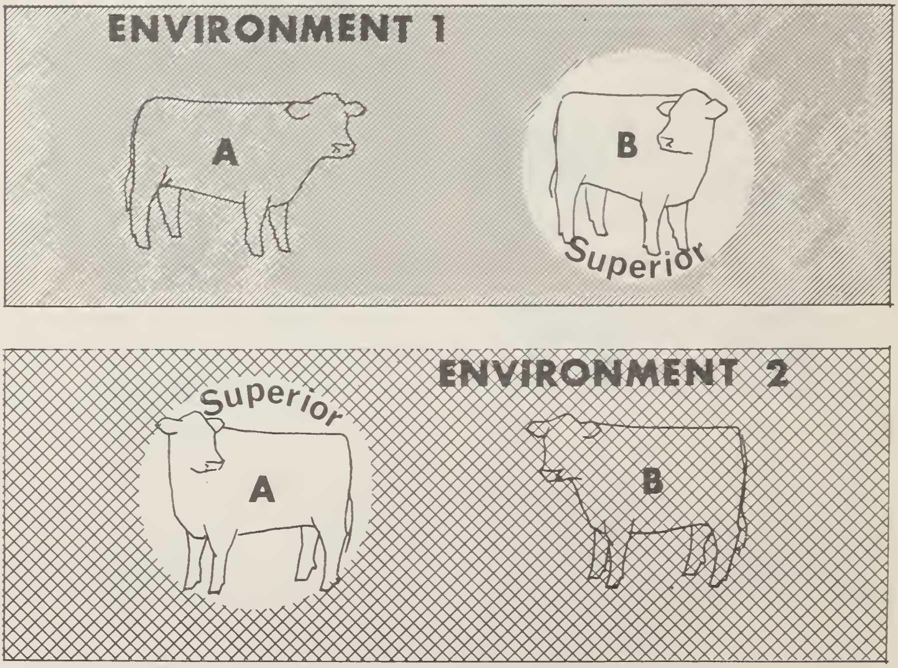
Some problems are inherent in the utilization of heterosis. Generations among females in the herd overlap. The percentage of different lines or breeds represented in the females will vary, because only approximately 15 or 20 percent of the female herd is replaced each year. Several different age and breeding groups are present in a herd at a given time. More than one breed of bulls must be in service at a time if bulls are used that combine most

favorably with the specific females from the different breeding groups. This requires more than one breeding pasture.

Although perhaps none of these problems is insurmountable, relatively large herds that can use several breeding pastures are indicated so that females of different crosses can be separated and bred to appropriate sires. However, if artificial insemination is used this is not a major problem.

GENETIC ENVIRONMENTAL INTERACTIONS

Genetic environmental interactions refer to the extent to which the same genes contribute to superior performance in different environments. For example, assume two groups or lines of cattle—A and B. If line A is superior in environment 1 but line B is superior in environment 2, a genetic environmental interaction exists. The extent to which cattle superior in one environment maintain that superiority over a wide range of environments is not known. Very little research has been conducted to evaluate the importance of genetic environmental interactions on performance traits of beef cattle. Little is known about the range in adaptability of different kinds and types of beef cattle to the different climatic conditions and environmental regimes in which they are produced.



The importance of genetic environmental interactions on economic traits of beef cattle needs further evaluation.

Research on the adaptability of different types of cattle to different systems of production is now underway (1968).

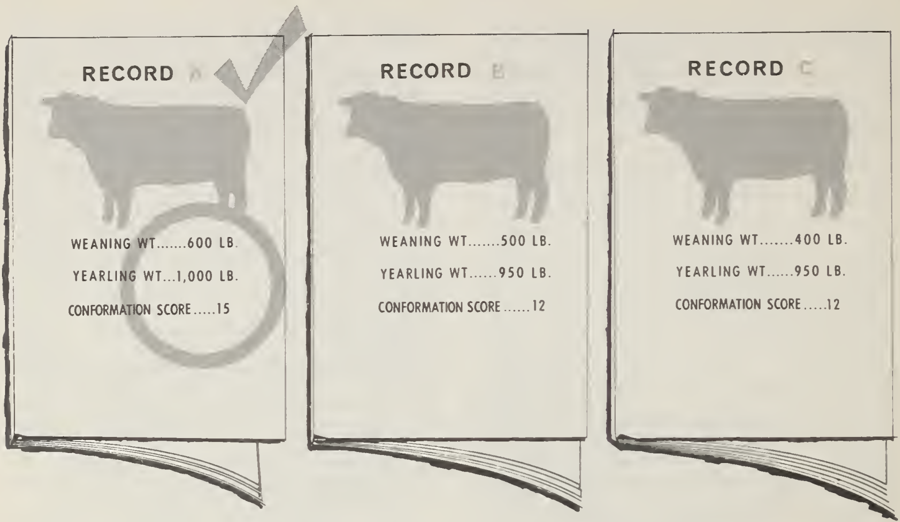
Beef cattle provide a means of utilizing the feed resources over a wide range of environments (climatic conditions) and in various types of production programs. The environments in which beef cows are carried range from the lush improved pastures of the Corn Belt and southeastern regions to the sparsely vegetated desert ranges of some of the Western States. There is basis to question whether the genetic makeup capable of the maximum response in one environment is the same as the one capable of maximum response in the other environment. For example, is the same cow capable of the most effective utilization of the feed resources in the two environments in terms of calf weaning weight? To obtain maximum use of the feed resources available, the genetic makeup that is best adapted to each situation is the one toward which specific breeding programs should be directed.

An evaluation of genetic environmental interactions and of selection for adaptability to specific climatic conditions and production programs is important to making correct decisions regarding the most effective breeding plans for the maximum utilization of available feed resources.

There are some indications of the importance of adaptation in beef cattle. Evidence includes the seemingly superior performance in some traits of cattle possessing some Brahman breeding under the subtropical conditions of the Gulf coast region. Yet, even in this region, the more the environmental conditions are improved, the less the advantage of the Brahman breeding in these traits. In the more temperate regions, cattle with some Brahman breeding do not seem so well adapted as cattle with British ancestry. More specific questions involving the matter of adaptation relate to specific production programs and practices.

The beef cattle industry is characterized by the movement of breeding stock to conditions greatly different from those in which they and their parents were selected. Such movement also characterizes feeder and replacement cattle for commercial production. The most effective use of the feed resources of this country necessitates movement of many feeder cattle. Perhaps little can be done in this situation even if adaptation is of major importance. However, the great amount of movement of breeding stock, particularly herd bulls, that characterizes the purebred segment of the industry is an undesirable practice if adaptation is of major importance.

Until the importance of genetic environmental interactions is fully evaluated, the wisest course of action for breeders is the selection of breeding stock under environmental conditions that are comparable with those under which their progeny are expected to perform.



Records of performance provide a basis for selecting genetically superior animals.

USE OF RECORDS

Traits of economic value are commonly referred to as performance traits and include all traits that contribute to both efficiency of production and desirability of product. Record of performance is the systematic measurement of traits of economic value and the use of these records in selection. The function of record of performance is to help find individuals that are genetically superior in all economically important traits so that they may be used for breeding.

The objective of any system of measurements is to make possible the evaluation of differences between animals. The preferred measurements are those that give the most accurate estimate of the breeding value or genetic merit of an animal relative to the others in a herd. Records increase a breeder's knowledge of differences between animals and thus increase the accuracy of his selections.

Research on beef cattle breeding has demonstrated that appreciable genetic improvement can be made in most traits of economic value by selection on the basis of differences in individual performance. This is indicated by the estimates presented in table 2. Such research has involved methods of measuring these traits and estimating their heritability and developing selection procedures for traits that contribute to both productive efficiency and carcass merit.

The systematic measurement of differences among animals in the traits of economic value, the recording of these measurements, and the use of the records in selection will increase the rate of genetic improvement.

Performance records of animals should be adjusted to eliminate

known environmental differences between animals so that genetic differences will be a larger part of the total differences measured or observed. Adjustments should be made for differences in age, sex, age of dam, and any other "environmental" variable that can be measured or evaluated. Because any increase in environmental variation tends to obscure genetic differences and decrease the effectiveness of selection, every precaution should be taken to measure economically important traits as accurately as possible. For example, an effort should be made to equalize "fill" in animals before they are weighed, because errors in weighing decrease the accuracy of selection. Fill can be equalized somewhat by removing water and feed for a 12-hour interval before weighing and by recording more than one weight. This applies to both initial and final weights.

Record of performance is useful primarily to provide a basis for comparing cattle handled alike within a herd and not for comparing differences between herds. This is because large environmental differences due to location, management, and nutrition are likely to exist between herds. It is difficult to adjust accurately for these differences. Genetic differences between herds do exist, but large environmental differences make the evaluation of genetic differences extremely difficult.

Average weaning weights of 500 pounds may be realistic in some environments and in some production programs; whereas, 350-pound weaning weights may be reasonable under more adverse conditions. Yet, beef cattle may provide the most desirable means of utilizing the land under both conditions. Furthermore, the genetic merit of a herd weaning 350-pound calves may be equal or even superior to that of a herd weaning 500-pound calves. Standards of performance expressed as deviations from individual herd or group averages are advisable for making comparisons within a herd, but comparisons between herds based on minimum standards of performance can be undesirable and misleading.

Minimum standards of performance for the various production and carcass traits have been considered in some record-of-performance programs. Because of the variation in environmental conditions and production programs, standards involving between-herd comparisons may tend to give preference to herds carried under superior environmental conditions rather than those that are genetically superior.

Comparison of animals within a herd that are subject to different environmental conditions, such as having part of the calves on nurse cows, is as objectionable as comparison of records from different herds. If variations in treatments exist, comparisons should be restricted to animals treated alike unless appropriate adjustments can be made for treatment effects.

All economically important traits

that are heritable should be evaluated for all animals in a herd. An effective record-of-performance program should be compatible with practical management regimes. Cattle should be evaluated under the approximate environmental conditions in which their progeny are expected to perform.

Over a period of time, the inherent productivity of any herd depends largely on the genetic merit of the bulls used. From the standpoint of genetic improvement for the entire beef cattle industry, record of performance will have greatest impact in purebred or seedstock herds. Commercial producers can use record of performance to cull cows, to select replacement heifers, and to evaluate bulls on their progeny's performance where progeny groups are kept under comparable conditions. Since approximately 40 percent of all heifers must be saved for replacements just to maintain a herd, opportunity for selection among females is limited. Commercial producers can also make effective use of record of performance by selecting bulls on the basis of records from purebred or seedstock herds that are on a systematic record-of-performance program. In selecting herd bulls from their own herds as well as from other breeders' herds, purebred breeders should evaluate prospects on the basis of their records as compared with the herd average.

The goals in record of performance are not greatly different from those that have always been sought by progressive breeders. The principal differences lie in a systematic recordkeeping program and the use of these records in making selections. Record of performance up to slaughter requires no new or additional facilities except a scale and forms for keeping records.

The principal features of a good record-of-performance program are as follows:

1. All animals are given equal opportunity.
2. Systematic, written records are kept of all economic traits on all animals.
3. Records are adjusted for known sources of variation, such as age of dam, age of calf, and sex.
4. Records are used in selecting replacement stock and in culling poor producers.
5. Nutritional program and management practices are practical and compatible with those where progeny of the herd are expected to perform and are uniform for the entire herd.

No effort has been made in this bulletin to include sufficient detail to provide sole guidance for an individual record-of-performance program. Methods differ slightly in different areas, and breeders are advised to adopt those generally in use in their areas or sponsored by their breed association.

The relative emphasis put on the different traits may vary in different herds, but the attention that each trait receives should be based primarily on its heritability and economic importance to the entire

beef cattle industry. Keeping records does not change what an animal will transmit; records are used to locate the genetically superior individuals. If genetic improvement is to be accomplished, the superior animals must be selected.

MAJOR PERFORMANCE TRAITS OF BEEF CATTLE

All traits of economic value should be considered in selecting beef cattle. The major traits influencing productive efficiency of highly desirable beef are (1) reproductive performance, or fertility, (2) mothering or nursing ability, (3) rate of gain, (4) efficiency of gain, (5) longevity, and (6) carcass merit.

Reproductive Performance, or Fertility

A high level of reproductive performance, or fertility, is basic to an efficient beef industry. It is fundamental for making genetic improvement because increased calf crops decrease the percentage that must be saved for replacement and thus increase the selection differential. Efficient cow-calf operations are fundamental to an efficient industry, and no single factor in commercial cow operations has a greater bearing on production costs than does calf crop. With a higher percentage of our total beef cattle population composed of cows, fertility is an increasingly important trait from the standpoint of total industry efficiency. Both the male and the female should be considered in selecting for fertility, as reduced calf crops can be the result of sterility or partial sterility of either.

Reproductive performance, or fertility, is a complex trait. So many random, or chance, environmental factors affect fertility from the time a cow is turned with a bull until her calf is normally weaned that fertility in any given year reveals little of the real genetic differences among cows. Better measures of fertility are needed for both cows and bulls.

Because of the importance of reproductive performance, or fertility, to efficient production, it must command some attention in a breeding program even though research results indicate that heritability of this trait is low and rate of improvement will be slow. There are reported instances where close culling for fertility has improved calf crops. In purebred herds, consideration should be given to culling open cows if they are below average in previous production and all cows open in successive years regardless of production. This assumes that no reproductive disease problems exist. Herd bulls should be selected from cows with good fertility records, be sired by bulls of high fertility, and show high fertility themselves as measured by their ability to settle cows.

In herds where reduced calf crops are a problem, close attention to feeding, disease control, and management practices are definitely indicated. Reproductive diseases markedly influence fertility. Level

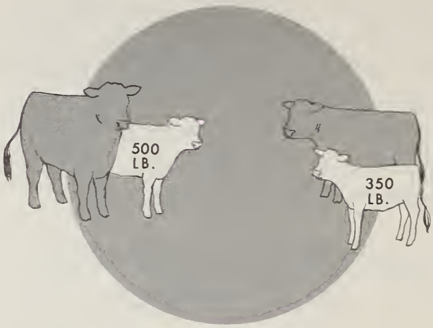
of feeding—particularly level of energy, vitamin A, protein, and phosphorus—is important. Management of bulls, size of pastures, and distribution of water may be related to whether cows conceive during the normal breeding season. Many breeders and commercial producers can profitably give greater attention to these items in increasing calf crop.

Birth Weight

Recording birth weight is optional in a record-of-performance program. An advantage of knowing birth weight is in having a more accurate measure of gain from birth to weaning. Direct selection for heavier birth weights would not seem desirable because of the increased likelihood of calving difficulty. Selection for traits that are of major economic importance should favor selection toward the optimum birth weight. There is a high positive genetic correlation between birth weight and postnatal gain. Information on birthweight by sire progeny groups, therefore, may be useful in deciding which sires to use for their second breeding season, since often this is the only progeny information available at the time a decision must be made.

Nursing or Mothering Ability

Weaning weight of calf is used as a measure of mothering ability. The calf's own genetic impulse for growth is confounded with mothering ability by this procedure, but this is not a serious handicap since



The ability to wean heavy, vigorous calves is an important economic trait that can be improved by selection.

half of the growth impulse of the calf is transmitted by the dam. The ability to wean heavy, vigorous calves is necessary for efficient cow-calf operations. With the trend of marketing cattle at younger ages, weaning age represents a higher proportion of total age at market time and increases the relative importance of weaning weight. Increasing the pounds of calf produced per cow increases efficiency because certain fixed costs such as veterinary, labor, and bull service are on a per-head basis. Feed costs for cows seem to be rather closely related to size of cow, but faster gains of calves decrease feed requirements per unit of gain among cattle of the same breed.

It is emphasized that the objective is to increase weaning weight relative to mature cow size. Thus, pounds of calf achieved for each unit of cow weight maintained may be a good measure of efficiency of operations from the standpoint of returns per unit of feed.

Selection of bulls and replacement

heifers that have heavy weaning weights relative to the herd average will lead to genetic improvement in mothering ability. In selecting for increased weaning weight, the breeder often selects not only for mothering ability but for the calf's own ability to grow. However, research information indicates that selection among cows for mothering ability should be reasonably effective. This can be accomplished by selecting cows on the basis of the weaning weights of their calves, since cows that wean calves heavier than the herd average in one year are more apt to produce calves heavier than average in succeeding years.

Differences in mothering ability can be evaluated about as accurately on the basis of 112-day calf weights as on the conventional weaning age of approximately 200 days. If calves are creep-fed, 112-day calf weights are perhaps preferable. Adjustment for differences in age of dam, sex of calf, and age of calf is necessary, since these factors influence weaning weight. In adjusting for differences in calf ages, it is recommended that average daily gain from birth to weaning be used for each calf (subtract actual birth weight, calculate average daily gain, and adjust to standard age for the group).

Mothering ability of cows may be compared within groups of the same sex of calf and of similar age of cows if numbers are large. This avoids an adjustment for differences in sex of calf and age of dam. The most accurate adjustment factors for sex of calf and age of dam are those developed in the herd in which they are used, provided the data are not biased by selection or management differences and the herd is large enough for reliable estimates to be made. Adjustment factors for smaller herds should be developed from herds with similar management regimes. Records are more accurate where the calving season is relatively restricted so that major differences in age and seasonal influences are avoided. Since weaning weight is used as a measure of mothering ability, it is important that all calves be treated the same (such as all or none be creep-fed) so that the major variable is difference in nursing ability of the cows.

Growth Rate

Growth rate is important because of its high association with efficiency of gain and its relation to fixed costs, such as veterinary, building, and labor, that tend to be on a per head or per unit-of-time basis. In most instances, differences in growth rate have been measured in time-constant, postweaning feeding tests. Results indicate that differences in growth rate can be appraised rather accurately in this manner. A post-weaning period of at least 140 days is required to measure differences in growth rate. This minimum length is based on rather uniform initial weights, condition, ages, and previous treatments. Final weight at 12 to 18 months (standardized for age differences) is probably a bet-

ter measure of genetic differences in growth rate than any component of final weight (that is, birth weight, preweaning gains, and postweaning gains).

Final weight at a standard age of 18 months seems to be a good measure of growth rate, and it fits the management programs of many purebred herds. Bulls can be carried on a relatively low level of concentrate feeding (4 to 5 pounds of concentrates plus full feed of roughage) their first winter and fed at a higher level of concentrate either on grass or in drylot during their yearling summer. By this procedure, bulls are developed at a high-enough level of feeding and over a long-enough period for genetic differences in growth rate to be expressed, and a good appraisal of growth can be made. Bulls handled in this manner are in good sale condition at a desirable age and season. Postweaning gains are measured for approximately 350 days and gains made in this period can be added to 200-day weaning weight, appropriately adjusted for age of dam, to arrive at an adjusted 550-day weight. Final weight and grade at somewhere near normal market age for a high percentage of slaughter cattle seems to be of most interest on an industrywide basis. The use of postweaning gain alone as a measure of growth could foster poor milking ability because of compensatory gains, in that a poor feed supply in one period tends to be followed by a period of increased rate of gain.

An alternate program for measuring growth rate in bulls is to feed at a higher level and for a shorter period immediately after weaning. Bulls may be put on feed when they are weaned and full-fed for 5 to 6 months a ration of from approximately equal parts of concentrates and roughage to two parts concentrates and one part roughage. In this program an adjusted final weight at 365 days can be used as a measure of differences in growth rate. For example, adjusted 365-day weight may be obtained by adding the gain made in a 165-day postweaning period to 200-day weaning weight, appropriately adjusted for age of dam.

Or the postweaning period may be intermediate to the two just described. For example, a postweaning period of 252 days with an adjusted final weight of 452 days may be used as a measure of difference in growth rate.

Research results indicate that a reasonably high level of feeding is desirable to appraise differences in

Adjusted yearling weight is an important economic trait that can be improved by selection.

growth rate most accurately. If a lower level of feeding is used, the period for measuring differences in growth rate should be longer. However, it is recommended that a relatively low level of feeding (to promote gains of ¾ to 1 pound per day) be used for heifers during their first winter. Research results indicate that full feeding a high-concentrate ration during the first winter may interfere with reproductive performance and mothering ability. Because a high percentage of heifers must be kept for replacements, there is not much opportunity to select among heifers for differences in growth rate. Hence, from this standpoint, very little can be gained from the heavy feeding of heifers. In selecting heifer replacements for differences in growth rate, it is suggested that long yearling age (approximately 18 months) be used, with adjustments made in the same manner suggested for bulls (by adding the gain made after weaning to weaning weight, adjusted to a constant age, and appropriately adjusted for age of dam). This assumes that heifers are carried at a relatively low level of feeding during their first winter. If heifers are bred as yearlings it may be desirable to make selections before 15 months of age. This can be done effectively with a 252-day postweaning period and adjusting final weights to 452 days.

The relation of growth rate to differences in composition of gain is of importance. For example, a 600-pound carcass with 30 percent fat trim will yield approximately the same amount of edible meat as a 470-pound carcass with 10.5 percent fat trim. Such differences in fat trim have been observed in carcasses of the same quality grade. In considering differences in total gain, it seems appropriate to be concerned with differences in composition of gain. Increased rate of gain is of little value if the additional gain is due to fat rather than muscle growth.

Efficiency of Gain

Efficiency of gain is one of the most important economic traits of beef cattle. Efficiency of gain is difficult to estimate because individual feeding and adjustments for differences in weight are necessary, since increased weight is associated with higher feed requirements per unit of gain.

Present (1968) information indicates that genetic improvement can be made in efficiency of gain by selecting for it through rate of gain. It is therefore recommended that breeders depend on differences in rate of gain as an indicator of efficiency of gain rather than incur the added expense of individual feeding. However, if a breeder desires to feed individually and adjust the records for differences in weight in order to measure differences in efficiency of gain, this is more accurate.

Longevity

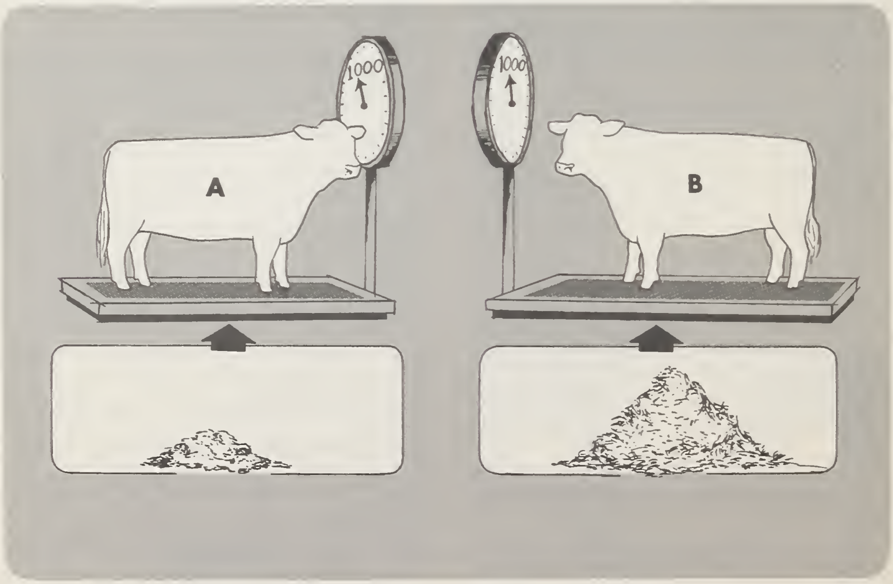
The longer animals remain productive in a herd, the fewer replace-

ments will be needed and thus the costs of growing out replacements to productive age will be reduced. However, the longer an animal remains in a herd, the longer will be the generation interval, which may reduce the rate of genetic improvement from selection. Breeders of purebred cattle or seedstock herds should be concerned with making genetic improvement in longevity so that commercial beef cattle populations will be productive at older ages. Yet, a fairly rapid turnover of generations in purebred herds is desirable for making a maximum rate of genetic improvement in other traits of economic value.

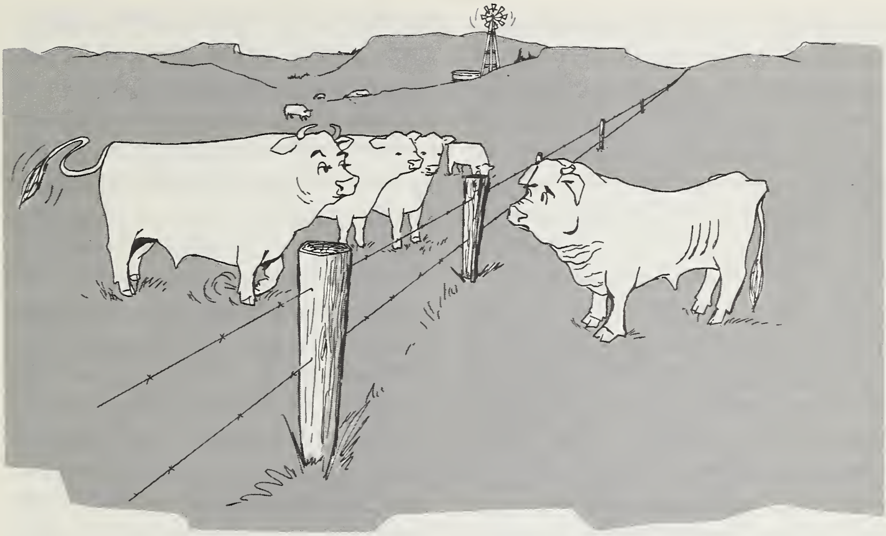
With the trend toward marketing cattle at younger ages and somewhat lighter weights, a higher percentage of the beef cattle population must be cows in order to produce the same amount of beef. This higher proportion of cows tends to make longevity of greater economic importance from an industrywide standpoint. Longevity in bulls is important because it decreases the annual cost of bull service.

The major factors affecting longevity are sterility, unsoundness of feet and legs, eye trouble (cancer eye), udder trouble, and unsound mouth. Research has shown susceptibility to cancer eye is heritable, and selection against it should be reasonably effective. However, resistance to cancer eye is a trait that can be measured only late in life.

Selection for longevity must be confined primarily to indicators such as structural soundness and to pedigree information (selection of close relatives of individuals that have had a long productive life).



Efficiency of gain—differences in amount of feed required to produce a 1,000-pound animal—is an important performance trait in beef cattle.



Longevity is important to the commercial producer of beef cattle.

There is a certain amount of automatic selection for fertility and longevity, because animals that remain in a herd long enough to produce a large number of offspring tend to have a larger number saved for replacements.

Carcass Merit

Carcass merit is of fundamental importance to the beef cattle industry. Desirability and price of product are the major factors affecting consumption. In selecting for improved carcass merit, the factors that contribute to carcass desirability and their relative importance must be known. In selecting among breeding animals, the conformation items indicative of desirable carcass traits and ways of measuring or evaluating differences in these traits in live cattle must be available.

Research in many States indicates that the American public desires beef with a high percentage of lean as compared to fat and bone and that the lean must be tender, flavorful, and juicy. The maximum development of muscling is desired in the regions yielding the more preferred, or higher priced, cuts—the back, loin, rump, and round.

The grade of a carcass is determined by a composite evaluation of its conformation and the marbling and firmness of its lean in relation to its maturity. Maturity is evaluated from ossification changes that occur in the skeletal system and from the color and texture changes in the lean. Marbling is finely dispersed fat within the muscle; research information indicates that it contributes to juiciness and flavor but that its relation to tenderness is low. Among carcasses from beef

breeds that are similar in maturity, marbling is the major factor that contributes to quality grade. The amount of outside fat on a carcass is not a factor in determining its quality grade. Furthermore, the quantity of outside fat on carcasses is not closely related to their marbling. This means that there is a great deal of variation in the amount of outside fat among beef carcasses—and slaughter cattle—of the same quality grade. Large differences in marbling also occur among carcasses of cattle fed and managed in the same manner. Research has also shown that the ability to develop marbling is rather highly heritable. There are no known reliable indicators in the live animal for predicting marbling independent of apparent fatness. The length of time on feed and the energy content of the ration seem to be the best guides for predicting marbling in live steers.

Thickness of muscling as measured by rib-eye area is one of the more highly heritable characteristics in beef cattle; therefore, selection for muscling should be effective.

Tenderness is probably the most important factor affecting the palatability of beef. And research indicates that tenderness is a trait with a fairly high heritability among animals of similar ages. Therefore, if information can be obtained on tenderness, selection for this trait could be an effective way of insuring that animals will produce tender lean. Tenderness also appears to be related to youthfulness. Therefore, if actual tenderness information cannot be obtained, selection of animals that will reach desirable market weights and grades at young ages would be an indirect means to the same end.

As was pointed out in the section on growth rate, difference in composition of carcasses (fat and lean) is a major factor influencing difference in retail value. Considerable variation in fat trim has been observed in carcasses of the same quality grade. Fat trim of Choice quality grade carcasses upon breakdown to retail cuts ranges from less than 10 percent to more than 30 percent, and it averages somewhere near 20 percent when cuts are trimmed to a maximum of three-eighths to one-half inch of outside fat. Thus, as was pointed out earlier, a 470-pound carcass with 10.5 percent fat trim will yield as much edible meat as a 600-pound carcass with 30 percent fat trim. The value of the fat trim is negligible in today's market.

The two primary factors that determine differences in the real value of carcasses are their yield of

Pounds of edible meat per unit of carcass weight and quality (palatability) of the meat determine carcass value.

boneless, closely trimmed retail cuts and their quality grade. Appraisal of differences in carcass merit should include both of these factors.

The Livestock Division, Consumer and Marketing Service, U.S. Department of Agriculture, has developed a system of grading beef carcasses that describes differences in carcasses for these two factors. In this system one grade—quality grade—identifies differences in quality of the meat and the other grade—yield grade—identifies differences in estimated yield of boneless, closely trimmed retail cuts from the round, loin, rib, and chuck. Estimated yield of these cuts as a percentage of carcass weight has been referred to as "cutability." These four wholesale cuts represent approximately 80 percent of the value of a carcass, and the relation between yield of boneless, trimmed retail cuts from the round, loin, rib, and chuck and from the rest of the carcass is high. Since differences in yield of boneless, trimmed retail cuts from the round, loin, rib, and chuck and differences in quality grade are the primary factors that determine differences in carcass value, a carcass merit index combining these two variables is appropriate for ranking carcasses on the basis of value and for ranking sires on the basis of the carcass value of their offspring.

Studies conducted by the Livestock Division, Consumer and Marketing Service, U.S. Department of Agriculture, have shown that the cuts from the round, loin, rib, and chuck can be predicted rather accurately from the fat thickness at the 12th rib, rib-eye area at the 12th rib, percentage of kidney and pelvic fat of the carcass, and carcass weight. Their prediction equation is as follows: Estimated percentage of boneless, trimmed retail cuts from round, loin, rib, and chuck (cutability) = 52.56 − 4.95 (single thickness of fat over rib-eye, [12th rib] inches) − 1.06 (percentage of kidney fat) + 0.682 (area of rib-eye, [12th rib] square inches) − 0.008 (carcass weight, pounds). For example, the computations for a 600-pound carcass with a rib-eye area at 12th rib of 10 square inches, 0.6 inch fat at 12th rib, and 3½ percent of kidney fat would be: Cutability = 52.56 − 4.95 (0.6) − 1.06 (3.5) + 0.682 (10) − 0.008 (600) = 52.56 − 2.97 − 3.71 + 6.82 − 4.80 = 47.90 percent.

For evaluating animals for carcass merit, it is desirable to combine cutability and quality grade of the carcass into a single index that will describe differences in carcass value. This can be done by combining differences in cutability and differences in quality grade of the carcass into an index of carcass merit.

At recent price levels of Prime, Choice, and Good grades, a 2-percent change in cutability has approximately the same effect on value as a change of one full USDA grade in carcass quality. This can be expressed as 2-percent cutability equals 1 quality grade. An index describing this relation would

be: $I=\frac{\text{Cutability}}{2}+\frac{\text{Quality Grade}}{1}$.

Since it is desirable to use carcass quality grade to the nearest one-third grade, the correct relation between the values of cutability and grade can be obtained by using a descending scale with one unit change equated to each one-third of a grade and dividing the quality grade component of the index by 3. Thus, the index would be: $I=\frac{\text{Cutability}}{2}+\frac{\text{Quality Grade}}{3}$.

To simplify the index: $I=0.5$ Cutability+0.33 Quality Grade. This index can be further simplified by multiplying by a factor of 2 and the index would then be: $I=$Cutability+0.66 Quality Grade. For ease of computation it can be rounded to: $I=$Cutability+0.7 Quality Grade, with quality grade expressed to the nearest one-third of a grade.

Carcass quality grade may be coded to a numerical scale for computing a carcass merit index. Differences among carcasses in the index reflect differences in their real value, if both differences in cutability and carcass grade are weighted according to their relative economic values.

The following numerical values for carcass quality grades are suggested for use in computing indexes:

Carcass grade	*Numerical value*
High Prime	52
Average Prime	51
Low Prime	50
High Choice	49
Average Choice	48
Low Choice	47
High Good	46
Average Good	45
Low Good	44
High Standard	43
Average Standard	42
Low Standard	41

Table 5 shows the indexes for 10 carcasses as computed by $I=$Cutability+0.7 Quality Grade.

Any descending code scale for quality grade may be used, pro-

TABLE 5.—*Carcass merit indexes for 10 carcasses*

Carcass No.	Cutability	Carcass quality grade[1] U.S.D.A.	Carcass quality grade[1] Number code	Grade ×0.7	Index	Rank in value
	Percent					
1	50	Average Choice	48	33.6	83.6	5
2	47	Low Prime	50	35.0	82.0	6
3	51	Average Prime	51	35.7	86.7	1
4	47	High Good	46	32.2	79.2	8
5	53	Low Choice	47	32.9	85.9	2
6	53	Average Good	45	31.5	84.5	4
7	46	High Good	46	32.2	78.2	10
8	47	Average Choice	48	33.6	80.6	7
9	44	High Choice	49	34.3	78.3	9
10	54	Low Good	44	30.8	84.8	3

[1] Some groups are proposing establishment of a minimum quality level of Low Choice, because of the high demand for carcasses that grade Choice relative to carcasses that grade Good and lower.

vided one unit change is equated to one-third of a grade. Thus, 17, 16, and 15 may be used for high, average, and low prime, respectively, with a comparable descending scale for the lower grades.

If ages of the cattle are known, growth rate can be included in the index by adjusting carcass weight to an age-constant basis. Live weight adjusted for differences in age and multiplied by dressing percentage provides an estimate of carcass weight on an age-constant basis. Carcass weight (adjusted for age) multiplied by the carcass merit index yields an index of value of a carcass, or an estimate of its worth including growth rate, cutability, and quality of meat.

Sires may be ranked on the basis of the carcass value of their offspring. An index of value on the progeny of several different sires should provide a logical basis for ranking them on their most probable genetic worth for several economically important traits. The information is relatively easy to obtain.

While the suggested index may be improved with additional information, the principle is basic, i.e., differences in value are determined by differences in amount of salable meat and differences in quality of the meat.

In considering cattle from the same herd or breeding group (which would be the case in a breeding program) that are fed and managed alike, weight at a constant age is by far the most important factor affecting pounds of edible meat at a constant age. In fact, results from research show that differences in weight at a constant age account for approximately 90 percent of the variation in pounds of edible meat at a constant age. These results may be interpreted to mean that in the selection of cattle from the same herd, variations in growth rate should be given considerably greater attention than variations in fatness if pounds of edible meat at a constant age is a primary objective.

Conformation Evaluation in Beef Cattle

Performance traits other than carcass merit and structural soundness should be measured directly or through the indicators that have been discussed rather than through conformation.

Conformation is a performance trait to the extent that it contributes to carcass merit and longevity. Basically, the important conformation items are structural soundness, which may contribute to longevity, and beefiness (thickness of natural fleshing, or muscling), particularly in the regions of the cuts that contribute most to carcass value (back, loin, rump, and round).

Research is expected to develop new tools that will result in improved methods of evaluating conformation. Until these are perfected, it is recommended that breeders use the best current procedures for evaluating differences in the major items of conformation. The term "major" is emphasized and includes only items of conformation that contrib-

ute to carcass merit and longevity—correct skeletal structure or structural soundness, beefiness, or thickness of natural fleshing, particularly in the regions of the high-priced cuts, and an optimum finish at a relatively young age.

In evaluating differences in conformation, it is recommended that a score at weaning and one at the time of final weight (12 to 18 months of age) be obtained. The weaning score is probably of less value than final score; therefore, the greatest emphasis should be placed on the final conformation score at 12 to 18 months of age. Since this is somewhere near normal market age for a high percentage of slaughter cattle, it should help guard against producing the "wrong kind"—cattle that are either too early maturing or too late maturing. Size or weight is a measure of growth rate and should not be considered in evaluating conformation. However, it is difficult to score conformation completely independent of growth, since a thrifty, growthy animal that has been doing well just naturally looks better than one that has not done so well, even though they may be basically the same in the major items of conformation.

A scoring system may be simple or it may include considerable detail, including independent scores of each of the major items of conformation. One with greater detail helps to point out the items of conformation that are good and those that are deficient, such as feet and legs or other structural soundness and natural fleshing. A simple system tends only to group animals of approximately equal desirability from a conformation standpoint without indicating where they are deficient or superior. Each breeder should use a systematic scoring system, choosing for himself whether to use a simple or more complex one.

Research indicates that the differences in outside fat and differences in thickness of muscling can be appraised with limited accuracy by subjective evaluation in live cattle. Quality of the meat (which is determined by marbling, color, texture, and firmness in relation to age) and the amount of edible meat produced per unit of carcass weight are the primary factors that determine real differences in carcass value. The shape of muscling has some effect on desirability when the carcass is broken into retail cuts. Also, thickness of muscling, does affect yield of trimmed retail cuts. Among cattle that have been fed alike there is little relation between outside fat and marbling. Marbling is a primary factor in determining carcass quality grade. Therefore, a major objective in assessing differences in the indicators of carcass merit in live breeding cattle is to evaluate differences in the amount of lean relative to fat. Shape of muscling should also be considered. The other major factor to be considered in conformation evaluation is structural soundness, which is indicative of longevity.

Thus, the primary criteria of con-

formation evaluation in live cattle are (1) structural soundness, which is indicative of longevity, (2) thickness of natural fleshing, or muscling, and (3) thickness of outside fat. Differences in thickness of muscling, or natural fleshing, can be appraised to best advantage in the areas where the least amount of outside fat is normally present. These areas are the outside of the round and the forearm. Differences in outside fat are not greatly associated with differences in marbling and are a major factor affecting yield of trimmed retail cuts. Since outside fat in excess of three-eighths to one-half inch is trimmed off the retail cuts, amounts in excess of this are undesirable. Indicators of outside fat are fullness of brisket and flanks as well as evidences of patchiness around the tailhead and over the loin.

Research is in progress (1968) to develop techniques for objectively measuring differences in outside fat and muscling in live cattle. Until such techniques are perfected, a subjective score to reflect differences in these traits is recommended. In scoring for differences in fat thickness, an optimum amount of three-eighths to one-half inch is desired in slaughter steers and heifers. At yearling age, bulls have approximately 0.2 to 0.3 inch less outside fat than steers developed in a comparable manner. Thus, it does not seem that one needs to be greatly concerned by bulls that have less than the amount of outside fat that is optimum for steers, because most of our slaughter steers and heifers have appreciably more than the optimum amount. One of the real opportunities for reducing outside fat in slaughter cattle is to select bulls that have the minimum amount.

In bulls developed alike it seems reasonable to give independent scores for differences in (1) structural soundness, (2) thickness of natural fleshing, or muscling, and (3) outside fat.

A muscle score reflects differences in thickness of muscling in relation to length of long bones. Thus, muscle score generally reflects weight in relation to height. With two animals of the same weight but differing in height, the animal with less height will normally receive the higher score for muscling if they are approximately equal in outside fat. Preliminary information indicates that mature size may be highly associated with long bone length at yearling age. Thus, with two animals of the same weight as yearlings, but differing in height, the one with the greater height may be expected to have a heavier mature weight and a lower muscling score at yearling age.

On the basis of these preliminary results, selection for heavy weights at yearling age, along with a high muscling score, should result in growth curve with rapid early growth without excessive mature size. Thus, the use of a muscling score at yearling age may be a factor in selecting for optimum mature size. Major attention should be

given to yearling weight because of its great economic importance. Indications are that near maximum yearling weight may be obtained along with a high muscling score.

RECORDS INTERPRETATION

The systematic collection of records on economic traits, the making of appropriate adjustments of these records, and the development of records summaries provide the basis for effective selection for making genetic improvement. However, the effectiveness of a systematic record-of-performance program is dependent entirely on the extent to which records are used in making selection decisions.

It was emphasized earlier that most of the opportunity for selection should be used on traits of greatest economic value that have heritabilities high enough to effect a reasonable rate of improvement. Increasing the number of traits reduces the amount of selection that can be practiced for any one trait. Although fertility is a trait of great economic importance, it is low in heritability. Thus, rate of improvement in fertility is expected to be slow. On the other hand, yearling weight is a trait with high heritability, and it too is a trait of great economic importance.

It has been indicated earlier that yearling weight at a constant age accounts for more than 90 percent of the variation in pounds of boneless, trimmed retail cuts at a constant age. Thus, yearling weight adjusted to constant age is a trait that should receive major attention in selection.

The economic value of conformation score at yearling age is not so well documented as yearling weight. However, indications are that conformation score may be of considerable economic importance if it is based primarily on thickness of natural muscling and structural soundness.

Another trait of major economic importance is mothering ability, because heavy weaning weights are basic to an efficient beef cattle industry.

Thus, it is suggested that appropriately adjusted yearling weight and yearling conformation score based primarily on thickness of muscling and structural soundness, along with some attention to weaning weight, should be the primary criteria on which selections are based.

It is obvious that adjusted yearling weight is composed of weaning weight and postweaning gains. Thus, selection for yearling weight automatically gives attention to weaning weight.

Tables 6 and 7 provide an example of the basic records necessary for making effective selections. These are the records on the surplus bulls offered for sale at the Fort Robinson Beef Cattle Research Station in 1967. This is a U.S. Department of Agriculture station, and the research program at the station is cooperative between the Department of Agriculture and the Nebraska Agricultural Experiment Station.

TABLE 6.—*Record of performance for yearling bulls, Fort Robinson Beef Cattle Research Station, 1967*

Lot No.	Tattoo	200-day performance				452-day performance			
		Weight [1]	Weight ratio [2]	Number [3]	Score [4]	Weight [1]	Weight ratio [2]	Number [3]	Score [4]
1	BOCALDO COMET 3255		109		13		104		14
	Progeny average 1966		99	(16)	12. 1		97	(5)	12. 4
2	6336	493	109		13	1, 023	102		12
3	NEBRASKA COMET 3177		95		11		110		14
	Progeny average 1966		100	(23)	12. 2		100	(11)	12. 3
4	6161	435	96		13	1, 061	106		12
5	6228	506	112		14	1, 040	104		13
6	6410	461	102		11	1, 138	114		13
	NEBRASKA COMET 2187		89		12		103		15
	Progeny average 1965–66		102	(34)	12. 7		100	(17)	12. 6
7	6414	458	101		12	1, 081	108		12
	NEBRASKA COMET 2135		102		14		103		15
	Progeny average 1965–66		97	(44)	12. 5		97	(23)	12. 7
8	6098	508	112		13	1, 084	108		14
9	6147	484	107		13	1, 050	105		13
10	6212	489	108		14	1, 078	108		13
11	6287	511	113		14	1, 057	106		12
12	6432	464	103		12	1, 052	105		13
	NEBRASKA COMET 1109		107		14		103		16
	Progeny average 1964–65–66		101	(62)	12. 8		101	(32)	13. 2
13	6011	452	100		12	1, 073	107		12
14	6138	483	107		12	1, 095	109		14
15	6195	468	104		13	1, 037	104		13
16	6350	454	100		13	1, 063	106		14
17	6352	512	113		13	1, 069	107		13
	ASTER COMET 1064		102		13		109		13
	Progeny average 1964–65–66		99	(47)	12. 5		101	(18)	12. 5
18	6172	496	110		13	1, 129	113		13
19	6199	467	103		13	1, 052	105		13
20	6226	517	114		14	1, 092	109		12

See footnotes at end of table.

TABLE 6.—*Record of performance for yearling bulls, Fort Robinson Beef Cattle Research Station, 1967*—Continued

Lot No.	Tattoo	200-day performance				452-day performance			
		Weight [1]	Weight ratio [2]	Number [3]	Score [4]	Weight [1]	Weight ratio [2]	Number [3]	Score [4]
21	BOCALDO BARON 3241		102		12		113		15
	Progeny average 1966		95	(27)	12.3		97	(12)	13.1
22	6222	466	103		12	1,044	104		14
23	6239	504	112		14	1,089	109		13
24	NEBRASKA BARON 3029		110		13		115		14
	Progeny average 1966		97	(25)	12.2		100	(13)	12.8
25	6241	487	108		12	1,040	104		13
26	6344	386	85		11	1,040	104		13
	NEBRASKA BARON 2103		123		13		119		14
	Progeny average 1965–66		99	(39)	12.1		102	(20)	12.4
27	6267	497	110		12	1,036	103		13
28	6351	480	106		11	1,028	103		12
	NEBRASKA BARON 2097		105		13		112		14
	Progeny average 1965–66		102	(37)	12.3		101	(25)	12.2
29	6010	482	107		12	1,090	109		13
30	6208	507	112		13	1,055	105		13
	NEBRASKA BARON 1011		102		13		109		14
	Progeny average 1964–65–66		99	(52)	12.0		104	(24)	12.4
31	6129	482	107		13	1,056	105		13
32	6207	482	107		12	1,042	104		12
33	6283	466	103		12	1,068	107		13
	NEBRASKA BARON 1004		116		13		118		13
	Progeny average 1964–65–66		98	(61)	12.2		101	(33)	12.1
34	6075	487	108		13	1,075	107		13
35	6080	411	91		12	1,061	106		13
36	6113	463	102		13	1,091	109		13
37	6153	447	99		12	1,093	109		12
38	6359	439	97		12	1,023	102		13

	NEBRASKA ADVENT 3124		113		13		109		15
	Progeny average 1966		104	(20)	12.5		105	(12)	13.0
39	6119	483	107		13	1,103	110		12
40	6209	504	112		13	1,034	103		14
41	6327	429	95		11	1,075	107		13
42	FRONTIER ADVENT 3063		119		12		107		12
	Progeny average 1966		101	(21)	11.7		97	(10)	12.1
	NEBRASKA ADVENT 2245		113		14		105		13
	Progeny average 1965–66		101	(44)	12.7		99	(24)	12.4
43	6175	476	105		13	1,071	107		12
44	6387	482	107		13	1,094	109		14
	NEBRASKA ADVENT 2238		116		13		108		13
	Progeny average 1965–66		101	(44)	12.1		98	(22)	12.2
45	6277	470	104		12	1,030	103		12
46	6319	473	105		12	1,020	102		13
	BOCALDO ADVENT 1185		109		14		100		12
	Progeny average 1964–65–66		99	(61)	12.8		98	(29)	12.5
47	6027	466	103		13	1,040	104		14
	FRONTIER ADVENT 1032		129		13		115		13
	Progeny average 1964–65–66		108	(59)	12.2		103	(34)	12.0
48	6033	527	117		13	1,030	103		13
49	6049	457	101		11	1,044	104		12
50	6055	504	112		12	1,142	114		12
	Average all bulls	452	100	(205)	12.3	1,001	100	(205)	12.5
	Average sale bulls	476	105	(45)	12.5	1,064	106	(45)	12.8

[1] 200-day weights are adjusted for age of dam; 452-day weights are the 200-day weights plus the gain during the 252 days after weaning.

[2] Weight ratios for 200 days and 452 days are computed by dividing the bulls 200-day or 452-day weight by the average weight of all bulls. A ratio of 110 means an animal is 10 percent above average.

[3] The figures in the parentheses indicate the number of animals involved in computing the average ratios. The progeny averages for 200-day weight include both bulls and heifers; the 452-day averages are for bulls only.

[4] Scores follow the recommendations of the United States Beef Cattle Records Committee: 17–16–15: Cattle have no more than minor faults in any of the major items of conformation with outstanding muscular development and optimum outside fat. 14–13–12: Cattle have no more than moderate faults in their skeletal and muscular structure and muscular development average to superior. 11–10–9: Cattle may have moderate to severe faults in some items of skeletal and muscular structure and muscular development average to inferior.

TABLE 7.—*Record of performance for dams of bulls in 1967 sale*

Lot No.	Tattoo	Dam	Number calves weaned	Average weaning score	Average weaning weight ratio	Estimated breeding value [1]
1	3255	53263	4	12. 8	104	102
2	6336	63158	1	13. 0	110	102
3	3177	59471	2	11. 5	100	100
4	6161	59248	4	12. 0	95	98
5	6228	63109	1	14. 0	113	103
6	6410	55224	8	12. 3	106	102
7	6414	61233	3	12. 0	105	102
8	6098	63047	1	12. 0	108	102
9	6147	64199	1	13. 0	108	102
10	6212	60156	4	14. 0	112	104
11	6287	59021	5	13. 6	110	104
12	6432	59083	5	12. 8	102	101
13	6011	59080	6	12. 2	91	96
14	6138	62027	1	12. 0	108	102
15	6195	60197	4	12. 5	109	103
16	6350	59164	5	12. 6	102	101
17	6352	58154	5	12. 8	100	100
18	6172	59055	4	12. 5	99	100
19	6199	64034	1	13. 0	104	101
20	6226	59416	5	13. 8	113	105
21	3241	59460	2	12. 0	101	100
22	6222	59135	5	12. 4	109	103
23	6239	58148	6	12. 8	107	103
24	3029	57221	5	12. 2	102	101
25	6241	59051	4	12. 2	105	102
26	6344	60065	2	12. 0	95	99
27	6267	61193	3	12. 0	104	101
28	6351	61044	3	13. 0	110	103
29	6010	63035	1	12. 0	109	102
30	6208	63121	1	13. 0	114	103
31	6129	61132	3	13. 3	104	101
32	6207	64295	1	12. 0	109	102
33	6283	63014	1	12. 0	105	101
34	6075	59038	3	13. 3	113	104
35	6080	64175	1	12. 0	93	99
36	6113	62012	2	12. 0	99	100
37	6153	59460	5	11. 8	98	99
38	6359	64033	1	12. 0	99	100
39	6119	63082	1	13. 0	104	101
40	6209	59067	5	12. 6	112	104
41	6327	59453	3	12. 3	99	100
42	3063	60178	1	12. 0	118	104
43	6175	62025	2	13. 0	99	100
44	6387	62048	2	12. 0	101	100
45	6277	61169	3	12. 3	103	101
46	6319	61142	3	12. 3	97	99
47	6027	61048	3	12. 7	101	100
48	6033	61026	2	12. 5	108	102
49	6049	64030	1	11. 0	99	100
50	6055	59144	5	12. 4	104	102

[1]An estimate of breeding value for weaning weight based on her own weaning weight and the accumulated weaning weight (s) of her calves. This involves the use of estimates of repeatability and heritability of weaning weight.

The bulls listed for sale were surplus to the needs of a cooperative research project.

These tables (6 and 7) provide weight and conformation score information on all bulls from the entire calf crop, the bulls offered for sale, their sires, including sire progeny records, and on the weaning weights and scores of all calves from their dams. Weight ratios are used in the information presented in table 7: they provide a basis for making comparisons.

These tables (6 and 7) provide a basis for understanding the basis for collecting, summarizing, and interpreting the records on the primary traits on which most of the selection opportunity should be used.

Among the many items of interest in these tables (6 and 7) are the following:

1. The difference between the average weights and scores of the bulls offered for sale and the average of all bulls from the entire calf crop.
2. The difference among the bulls offered for sale in weights and scores.
3. The difference among the sire progeny groups in weight ratios and scores.
4. The difference among the dams of the bulls in weaning weight ratios, weaning scores, and estimated breeding value of the dams for weaning weight.

In reviewing these records, it should be kept in mind that the sale bulls were a selected group (above average in their adjusted 452-day weight) and, as evidenced by the records of their sires on their own performance, their sires were a highly selected group. It is obvious that approximately one-half of the sires will be below average (weight ratio of 100) in the performance of their progeny in yearling weight ratio.

If heritability were perfect, or 1.0, the sires would rank the same in their progeny averages as they do in their own performance. However, the heritability of adjusted yearling weight is only approximately 60 percent.

The same type of summaries would be appropriate for selecting heifers, since the basic procedures and criteria should be the same in both sexes.

CENTRAL TESTING STATIONS

Central testing stations are locations where animals are assembled from many herds to evaluate differences in some performance traits under uniform conditions. Present and potential uses of central testing stations include (1) estimating genetic differences between herds or between sire progenies in gaining ability, grade, ability to fatten, and carcass characteristics: (2) determining the gaining ability, grade, and fattening ability of potential sires as compared with similar animals from other herds: (3) determining gaining ability, grade, and ability to fatten under comparable conditions of bulls being readied for sale to commercial pro-

ducers; and (4) as an educational tool to acquaint breeders with performance testing.

It is important that the objectives of a central testing station be clearly defined and procedures designed to accomplish the objectives. Since specific objectives and procedures vary with location, only general principles will be discussed.

In beef cattle, nutritional level at one stage of life usually has carryover effects on performance at later stages. A poor feed supply in one period tends to be followed by a period of increased or "compensatory" gain when rations are increased. Conversely, a higher-than-normal level of feeding will likely be followed by a period of subnormal gains on a normal feeding regime.

Since pretest levels of nutrition and management usually differ from farm to farm or ranch to ranch, performance at a central testing station is influenced by pretest environment. From one standpoint, this is a serious disadvantage of central testing stations, since part of the observed differences at a station will be due to pretest conditions. It will nearly always be impossible to estimate the importance of these effects. However, carryover herd environmental effects will be less important than herd differences due to environment had all animals been fed for a comparable period in the herds in which they were produced. From this standpoint, central testing stations minimize herd environmental effects.

Bull buyers have to decide on (1) which herds to buy bulls from, and (2) which bull or bulls to buy within a herd. If the bulls are raised and fed entirely on the farm or ranch where dropped, the buyer has the nearly impossible task of deciding how much of the apparent superiority or inferiority of bulls in a specific herd is due to feeding and herdsmanship. Having them handled for part of their lives under standard conditions minimizes these effects and makes the task of the buyer easier, whether he is buying commercial bulls or herd sires for a purebred herd.

Similarly, if progeny test groups of steers from different herds are being fed out to determine the transmitting ability of the sires for growth rate, feed efficiency, and carcass characters, sire comparisons are more accurate if all progeny are fed under standard conditions for the final feeding period.

Central tests are of limited usefulness for estimating genetic differences among herds. The larger the herd size, the greater the number needed to adequately sample the herd. The precision of the tests will be greatly improved if five to eight progeny of each of two or more sires from each herd are tested each year. This permits assessment of within-herd differences to compare with between-herd differences. Further, efforts should be made to get a desirable sample of animals from each herd on test or little real information on herd differences will be accumulated. If central testing

stations are used to estimate genetic differences between herds, it is recommended that samples of those completing the evaluation be used in top-cross comparisons in commercial herds so that additional traits can be measured and the precision can be increased.

If the purpose is to evaluate individual potential sires, the number tested per herd or per sire is of no importance; but everyone concerned with the test should make a special effort to discourage between-herd comparisons if numbers from each herd are small. Preferably, bulls should be entered in this type of test only if they meet rigid qualifications for preweaning rate of gain and conformation score.

If the purpose is solely to develop bulls and make objective performance information available to prospective buyers, the number of bulls per herd or per sire is immaterial. To be most useful, however, large numbers should be fed at a single location so buyers will have an adequate number from which to choose. Tests of this kind would be most useful as a service to small breeders. If commercial-type feedlots were used, large numbers could be fed.

Influences of pretest environment on test performance can probably never be eliminated, but they can be minimized by the following procedures:

1. Accept animals for test or group them on test only within relatively narrow age ranges, preferably at or shortly after weaning, and from among animals whose pretest treatment has been similar in type of pasture dam was on, whether creep feed was offered, etc. It is important to evaluate differences in growth rate during the period of an animal's life in which growth is most important (before 18 months).
2. Have all animals delivered at a specific time and consider the period immediately after delivery to be an adjustment period. During the adjustment period the animals either can be fed the test ration and the data on gain disregarded or can be fed a low level standard ration. Optimum length of the adjustment period is unknown; periods ranging from 14 to 90 days have been recommended. Presumably, the longer periods would be more effective.
3. Test for adequate periods, preferably 150 to 180 days if the test is on a fairly high concentrate ration the entire time. Longer tests are desirable if the ration during the test period is high in roughage.

Influences of pretest environment can be minimized in appraisal of results if the final reports include both pretest and test gains. The principal danger of considering test gain only is that cattle on a sub-optimum feeding level before test, which did not permit full expression of their inherent ability to grow, are likely to compensate with inflated test gains. Evaluating animals on the basis of both pretest

and test gains avoids labeling an unduly high test gain as the animal's real gaining ability.

Preferable methods of doing this are (1) averaging pretest and test gains, or (2) if test starts immediately after weaning, computing a final weight as a standard weaning weight (for example, 200 days) plus test gain. The entire life of the animal must be accounted for: "loafing periods" of unequal or indeterminate length, which would tend to influence subsequent gains, should not be omitted.

The problem of compensatory gain is not limited to central testing stations, since within a herd the inherently fast-gaining calf whose mother was a poor milker is likely to have a low weaning weight with a correspondingly inflated postweaning gain. Comparisons, whether between herds at test stations or within a herd on an individual farm, should give emphasis to both preweaning and postweaning gains.

Central testing stations will be of greatest educational value if all concerned recognize that only a limited number of traits can be evaluated in them and that at best they are merely one phase of a complete performance evaluation program. One of the primary measures of the effectiveness of central testing stations should be the impact they have for increased herd testing for all economically important traits.

Central testing stations can increase problems in the maintenance of herd health. Proper precautions are essential to keep this problem at a minimum.

HEREDITARY DEFECTS OF BEEF CATTLE

A large number of hereditary defects of possible economic importance have been reported in all breeds of beef cattle and also among the dairy breeds. Perhaps the hereditary defect most widely known is "snorter" dwarfism. This defect occurred at troublesome frequencies in some herds in the late 1940's and early 1950's. Discrimination against lines of breeding known to carry this defect has reduced its frequency. This defect, as well as most other hereditary defects, is inherited as a simple recessive. That is, it is due to a single pair of genes that must be present together before the trait is expressed. Such a defect results from the mating of parents, both of which carry the defective gene.

Other types of hereditary dwarfism are due to different genes. "Comprest" dwarfism seems to be due to the action of a gene with incomplete dominance. In other words, the carrier individuals are "comprest," and an extreme type of dwarfism segregates from "comprest" × "comprest" matings. The "comprest" condition in Herefords and the "compact" condition in Shorthorns are probably due to the same gene. "Snorter" dwarfism has been authentically reported in both the Angus and Hereford breeds, and longheaded dwarfism has been re-

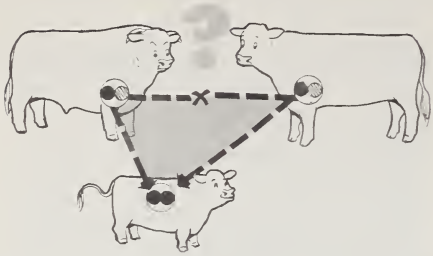
ported in the Angus breed. Long-headed dwarfism is also inherited as a simple recessive.

The most practical means of testing a bull for a *specific* defective recessive gene is to breed him to 16 females that are known to be carriers of the gene. To determine if a bull is a carrier of *any* genetic defect, the most appropriate test is on his own daughters. On the average, half of the daughters of a bull with a defective gene will be carriers of that gene. After 30 to 35 matings of a bull to his daughters without the occurrence of some genetic defect, one can be reasonably sure that the bull does not carry a genetic defect noticeable in the offspring. The percentage of bulls that are carriers of a hereditary defect inherited as a simple recessive that will not be detected with different numbers and kinds of test matings is presented in table 8.

Although many genetic defects

TABLE 8.—*Testing bulls for hereditary defects inherited as simple recessives*

Matings (number)	Percentage of carrier bulls that will not be detected when mated: To known carriers of a specific defect	Percentage of carrier bulls that will not be detected when mated: To own daughters or to unselected daughters of known carriers of a specific defect
	Percent	*Percent*
5	23. 73	51. 29
6	17. 80	44. 88
7	13. 35	39. 27
8	10. 01	34. 36
9	7. 51	30. 06
10	5. 63	26. 30
11	4. 22	23. 01
12	3. 16	20. 13
13	2. 37	17. 61
14	1. 78	15. 41
15	1. 34	13. 48
16	1. 00	11. 80
17		10. 32
18		9. 03
19		7. 90
20		6. 91
21		6. 05
22		5. 29
23		4. 63
24		4. 05
25		3. 54
26		3. 10
27		2. 71
28		2. 37
29		2. 07
30		1. 81
31		1. 58
32		1. 38
33		1. 21
34		1. 06
35		. 93



Hereditary defects should be considered in a constructive breeding program.

are present in all breeds of beef and dairy cattle and in all classes of farm livestock, defective genes can be coped with if breeders clearly understand them and plan their breeding programs accordingly. Increased frequency of genetic defects in a breed or population can be accounted for either by the gene producing an effect in carriers that causes them to be preferred to noncarriers or where, by chance, a defective gene happens to be present in a line of breeding that is favored and is used extensively by the industry. Either condition will increase the frequency of a defective gene in the population or breed.

Defective genes probably cannot be eliminated from our beef cattle populations; they are one of the hazards of breeders. But seedstock producers are responsible for keeping them in check so that they do not become a problem to commercial producers. This can be done most effectively by closely observing operations and by realistically approaching a solution once a problem arises. A realistic approach may require careful screening of herd bulls by progeny testing and the prompt elimination of those proved to be carriers of a defective gene.

If an abnormal calf is born in a herd, the breeder should establish the most probable cause of the abnormality. A limited number of developmental abnormalities may occur that do not have a genetic basis. Only by complete records will the breeder be able to establish the basis for abnormalities. If a breeder decides that an abnormality has a hereditary basis, he should breed away from the source of the trouble, so that the minimum damage will result to his herd and to others. This may be done by outcrossing to a linebred herd after a careful study of the outcross so that the same or an equally undesirable defect will not be introduced. Another means may involve the progeny testing of bulls from his own herd so as to assure that future herd bulls are not carriers of the gene responsible for the defect. The latter procedure may be indicated if the genetic merit of the herd is particularly high. If only a small percentage of the animals in a herd are possible carriers of the genetic defect, the best course is to eliminate those animals from the herd, provided their genetic merit is not superior to the remainder of the herd.

Since most abnormalities are inherited as simple recessives, both the sire and the dam of abnormal calves are carriers of the gene that caused the defect.

While it is unwise to use sons of bulls or cows known to be carriers of genes that cause a defect without

first progeny testing the sons, discrimination against lines of breeding involving animals several generations removed from a known carrier is unjustified.

Only one-half of the progeny of a bull that is a carrier of a defective gene will be carriers when the bull is mated to cows that are noncarriers. Thus, it seems more reasonable to handle such situations on an individual herd or individual bull basis than to discriminate against other herds descended from similar lines of breeding if they are not directly incriminated.

Breeders should approach problems of genetic defects on the same basis as all problems regarding an effective breeding program. First obtain the facts, then weigh the evidence, and proceed on a logical and systematic basis to make the most reasonable decision for coping with the problem. Such an approach should keep genetic defects in check. Genetic defects can be handled by individual breeders who have the courage to assume their responsibility to their fellow breeders and to the entire industry.

DEVELOPING BREEDING PLANS

To attain the maximum rate of genetic improvement in all traits of economic value in beef cattle requires a clear perspective of objectives and a planned breeding program for accomplishing them. Objectives should include all traits that are of economic importance to the industry. The traits in which the different segments of the industry are interested vary, but the breeder must be aware of the demands of all segments of the industry. The commercial producer is interested in cows that have long productive life and wean a high percentage calf crop of heavy, high-grading calves. The feeder demands rapid and efficient feedlot gains, and the packer and retailer are interested in cattle that will produce high-grading carcasses with a minimum of excess fat and the maximum yield of closely trimmed retail cuts from the wholesale cuts of greatest value.

The heritability, genetic association with other traits, and relative economic importance determine the attention each trait should receive in selection. Traits vary in heritability and economic value. The greater the number of traits selected for, the smaller the selection differential will be for any one trait. Traits of low heritability respond less to selection than do traits of high heritability. The opportunity for selection should be used for traits that will result in the maximum genetic progress for the traits of greatest economic value. Obviously, little can be gained and much can be lost by paying too much attention to traits of little economic value and traits of low heritability. While there are genetic differences between herds, evidence indicates that the large differences in feed resources and management programs between herds make it extremely difficult to compare the records of different

herds. Thus, comparisons should be among animals in the same herd.

Rate of improvement in most economically important traits of beef cattle will be relatively slow primarily because of the inherently low reproductive rate, the large number of traits of economic value, and the long generation interval. The low reproductive rate, which makes it necessary to keep a high percentage of the offspring, especially females, as replacements, and the large number of traits limit the selection that can be practiced for any one trait. However, most of the economically important traits have reasonably high heritability, fertility being the most notable exception. Even though improvement is slow, it tends to be permanent, accumulates from year to year, and is transmitted to future generations. Over a period of 15 to 20 years, production in a herd or breed that has been subjected to systematic selection for all economically important traits should be noticeably higher than in those where such effort is not made.

A systematic record-of-performance program with selection based on differences in records is basic to any planned breeding program. The choice of breeding plans and the details relating to them involve many considerations. In seedstock herds, if genetic merit is already high and if the herd is large, is not particularly deficient in some trait of major economic importance, and is relatively free of hereditary defects, a closed-herd program of line breeding may be desirable. One advantage of proceeding on a closed-herd basis is that the breeder knows the differences in performance of his own cattle better than another breeder's and is in a better position to evaluate differences in their most probable genetic worth.

In large herds where a relatively large number of sires are used in each generation, a closed herd can be maintained for extremely long periods without any appreciable increase in inbreeding if an attempt is made to avoid the mating of close relatives—sire-daughter, full-brother-sister, and half-brother-sister. In herds in which as many as 8 to 10 sires are used per generation, the decrease in performance and the reduction in genetic variation as a result of inbreeding will hardly be noticeable.

If the genetic merit of the herd is already high, it will be difficult to bring in an outcross that is genetically superior to some individuals in the herd. Also, in herds that are relatively free of genetic defects, the chance of increasing this problem with introductions of outside bulls is greater.

If the herd is not large and only a small number of sires are used in each generation, the level of inbreeding will increase more rapidly and performance and genetic variation in the herd will decrease. This decrease in genetic variation decreases the effectiveness of selection.

Whenever a genetic defect is troublesome in a herd, or when performance in some economically im-

portant trait is particularly low (some major deficiency exists in a herd), perhaps an outcross is indicated. Although the outcross should be selected to correct the deficiency, the other traits of economic value should also receive major consideration. Outcrossing, for any reason, in herds of superior genetic merit should be done only on a cautious and systematic basis. Minimum sacrifice in other traits is a primary objective when bringing in an outcross to correct some deficiency. In herds of superior genetic merit, only herds known to be outstanding in the trait of major interest and superior in all traits should be considered for outcrossing. Perhaps this may be another linebred herd. Certainly, records are as fundamental in making selections for outcrossing as they are in making selections from within the herd. After the outcross has been selected, a comparison with sires in the herd in a properly conducted progeny test is desirable before extensive use is made of the sires brought into a herd for outcrossing.

In herds that are only average or below in genetic merit, an outcrossing program may logically be the one of choice. However, since most of the opportunity for selection in beef cattle is in the bulls used, records for the herds where bulls are selected should be helpful in locating individuals that have superior genetic merit. Outcross sires from linebred herds is desirable. Commercial herds should follow a program of outcrossing.

Pedigree, individual performance, and progeny test information all have a place in a constructive breeding program. Certainly, young sires should be initially selected on the basis of pedigree and individual performance data. The extent that they are used in a herd will depend on their rank with other sires based on progeny test information. After progeny test information is available, it should be used in making decisions on selections among sires. In using progeny test information, it should be remembered that an increase in generation interval is involved. However, in herds of superior genetic merit, where increased accuracy is of fundamental importance, there is justification for using progeny test information more extensively than in herds only average or below in genetic merit. Perhaps in many superior herds old sires are used more extensively than they should be.

Since generation interval affects rate of improvement from selection, consideration should be given to keeping it relatively short. If a sire is truly superior, he should sire sons that have genetic merit that surpasses his own when he is bred to cows that are comparable in genetic merit to the population that produced him. The problem is one of devising an evaluation program based on use of records that aid in locating such sons. Perhaps one handicap to continued improvement in some herds has been the extensive use of an old sire without sufficient attention to locating sons to replace

Herd improvement is accomplished by replacing a sire with his superior sons.

him. When the old bull dies, the herd is left without sires that are superior to him. Continued improvement depends on use of herd bulls that are superior to the ones used in the previous generation.

Before a bull is used extensively in a herd, as would be the case with artificial insemination, it may be desirable to progeny test him for genetic defects on 30 to 35 of his daughters. There are many genetic defects in all livestock, and if a herd is following a linebreeding program, it is desirable to be sure that the bull to which the linebreeding is directed is not a carrier of genetic defects. Bulls that are carriers of defective genes that are likely to be a problem to a herd or breed should be discarded. The purebred segment of the industry is responsible for keeping such defects at a low level so that they will not become a problem to the commercial segment of the industry.

The breeding of cattle of truly superior genetic merit is a great challenge. Many decisions must be made on breeding plans, on selecting herd bulls and replacement females, and on the continued use of herd bulls after some information is obtained on the performance of their progeny. One difficult decision seems to be "dropping" a bull that still has a good market for his progeny even though the breeder may have determined that the bull is not contributing to the accomplishment of his goals and may be inferior to others in the herd.

The more a breeder knows about the animals in his herd and the more clearly he understands his objectives, the more frequently he should make correct decisions. Success in breeding superior beef cattle, like success in other ventures, depends primarily on the utility of the goals and the accuracy of decisions while working toward the goals. A complete record-of-performance program provides the basis for making correct decisions.

Goals can be attained only by those who have the objectivity to keep them in perspective and the dedication to remain steadfast in achieving them. They can be accomplished only by a planned breed-

ing program based on the systematic use of records for selection on all traits of economic value.

Progress in beef cattle breeding is relatively slow at best. The life of many purebred herds is not long enough to make appreciable improvement even though the goals of the breeder are sound and his program systematic. Continuity of operation with practical-sized herds and a well-planned breeding program with utility objectives are essential. Sound judgment with the minimum of bias and prejudice is required in evaluating records and in making selections. Breeding beef cattle, like any other business in a healthy economy, is highly competitive. To meet competition successfully, the breeder must produce a superior product. Real merit is necessary to keep a product in demand. This is certainly true with beef cattle.

The contributions to genetic improvement have been made and will continue to be made by those who have chosen goals based on utility. The successful breeders have not been faddists, but they have exercised commonsense and good judgment with the long-term outlook in mind. The acceptance and use of new ideas and information is essential to progress in any business.

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